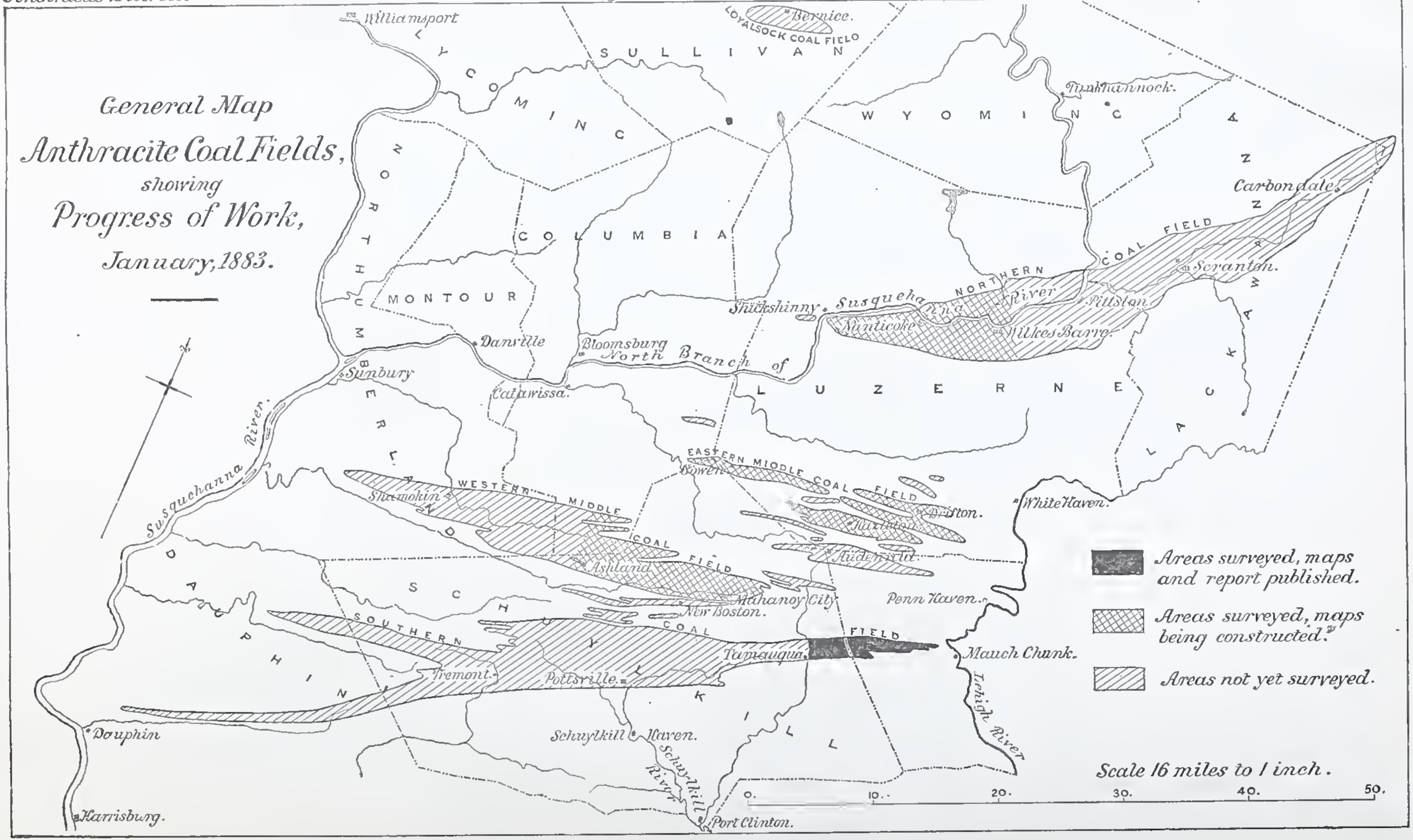
General Map
Anthracite Coal Fields,
showing
Progress of Work,
January, 1883.
Williamsport
LYCOMING
SULLIVAN
LOYALSOCK COAL FIELD
Bernice.
WYOMING
Tunkhannock.
Carbondale.
LACKAWANNA
NORTHERN COAL FIELD
Scranton.
Pittston.
Wilkes Barre.
Nanticoke.
Shickshinny.
Susquehanna River
North Branch of
NORTHUMBERLAND
MONTOUR
COLUMBIA
LUZERNE
Danville
Bloomsburg
Catawissa.
Sunbury
Susquehanna River.
EASTERN MIDDLE COAL FIELD
Bowen
Drifton.
Hazleton.
Audenried.
White Haven.
WESTERN MIDDLE COAL FIELD
Shamokin
Ashland
Mahanoy City
New Boston.
Penn Haven.
SOUTHERN COAL FIELD
Tamaqua.
Mauch Chunk.
Lehigh River
Tremont.
Pottsville.
SCHUYLKILL
DAUPHIN
Dauphin
Schuylkill Haven.
Schuylkill River.
Port Clinton.
Harrisburg.
Areas surveyed, maps and report published.
Areas surveyed, maps being constructed.
Areas not yet surveyed.
Scale 16 miles to 1 inch.
0. 10. 20. 30. 40. 50.

AA.

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

AA.

FIRST REPORT OF PROGRESS

IN THE

ANTHRACITE COAL REGION.

THE GEOLOGY OF THE

PANTHER CREEK BASIN

OR

EASTERN END

OF THE

SOUTHERN FIELD.

BY CHAS. A. ASHBURNER.

WITH AN ATLAS OF 13 SHEETS OF MAPS AND SECTIONS,
6 PAGE PLATES, AND 2 FOLDED PLATES.

HARRISBURG:
PUBLISHED BY THE BOARD OF COMMISSIONERS
FOR THE SECOND GEOLOGICAL SURVEY.
1883.

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FIRST REPORT OF PROGRESS,

ANTHRACITE SURVEY.

Chapter III.

Chapter IV.

Chapter V.

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Chapter VII.

LIST OF ILLUSTRATIONS IN ATLAS.

Southern Anthracite Field, Vol. I

Thirteen (13) sheets as follows:

Mauch Chunk, Mine Sheet No. I,
Lansford, " " " II,
Tamaqua, " " " III,

drawn on a scale of 800 feet to 1 inch, $\frac{1}{9600}$ths of nature, showing the plan of all the mines in the Panther Creek Valley, and the shape of the floor of the Mammoth bed, where mined, and its most probable structure in undeveloped areas, by contour curve lines, 50 feet apart.

One topographical sheet, scale 1,600 feet to 1 inch, $\frac{1}{19200}$ths of nature, showing the topography of the surface of the Panther Creek Valley, by contour curve lines, 10 feet apart, by R. P. Rothwell, Mining Engineer.

Three cross section sheets, scale 400 feet to 1 inch, $\frac{1}{4800}$ths of nature, showing the geological structure of the coal basins, by 12 cross sections, &c.

Three columnar section sheets, showing the thickness and character of the coal measures, scale 40 feet to 1 inch, $\frac{1}{480}$ths of nature; of the coal beds, scale 10 feet to 1 inch, $\frac{1}{120}$th of nature; and of the Carboniferous (Pottsville) Conglomerate, scale 100 feet to 1 inch, $\frac{1}{1200}$ths of nature.

Three miscellaneous sheets as follows:

Sheet No. I, containing a diagram showing the surface area of the Panther Creek Coal Basin, underlaid by the Mammoth bed (E or Top Split,) and the actual area of the floor of the coal bed developed into a horizontal plane, scale 2,400 feet to 1 inch, $\frac{1}{28800}$ths of nature; accompanied by tables showing the surface areas of the basin, underlaid by the G and F (Upper and Lower Red Ash,) Mammoth (E,) and Buck Mountain coal beds, together with the actual area of the floor of each coal bed in acres and square miles.

Sheet No. II, containing a *preliminary* General Map of the Anthracite Coal Fields of Pennsylvania and adjoining counties, scale $\frac{1}{300000}$ths of nature, columnar sections of the Coal Measures in prominent localites, and a list of the Operating Collieries and their production in 1881.

Sheet No. III.—Diagram and tables showing the annual production of anthracite coal in Pennsylvania, since 1820, and the amount produced in each region, together with the tonnage of the transporting companies since 1870. Compiled by P. W. Sheafer, Mining Engineer, and John H. Jones, accountant of the transporting companies.

List of Plates Bound in the Report.

List of Cuts in the Text.

LIST OF ERRATA ON ATLAS SHEETS,

"SOUTHERN ANTHRACITE FIELD, VOL. I."

Mine Sheet No. III.

Elevation of "second level," Tunnel No. 8, should be 756′ instead of 736′.

Elevation of "third level," Tunnel No. 8, should be 588′ instead of 589′.

Cross Section Sheet No. III.

The distance between cross sections Nos. 1 and 2 should be 10,900′ instead of 7,300′.

The distance between cross sections Nos. 5 and 6 should be 9,300′ instead of 9,100′.

The bearing of the plane of cross section No. 7 is S. 16° 20′ E. instead of S. 18° 20′ E.

Columnar Section Sheet No. I.

In section No. 4, the total thickness is 465′ 11″ instead of 468′ 11″, and the total coal is 114′ instead of 112′.

In section No. 12, the thickness of the coal bed (4′) next below the Red Ash bed is placed on the right-hand side of the section; it should be on the left. The total coal should be 56′ instead of 52′.

Columnar Section Sheet No. II.

In section No. 46, the thickness of the second stratum from the top should be 6′ 6″ instead of 66′; the thickness of the lowest stratum should be 405′ instead of 305′, and the total thickness should be 1111′ 1″ instead of 1011′ 1′.

In section No. 48, the number (24′) after the bracket and before the words "Nut Conglomerate," about the middle of the section, should be 25′. The total thickness should be 905′ instead of 878′.

Miscellaneous Sheet No. I.

The second sentence of the note under "Table V" should read: The developed Area of the Coal Bed was ascertained by proportion, based upon the relation of the Surface Area underlaid by the Mammoth (E) Bed, to the constructed Developed Area of the Bed itself.

Miscellaneous Sheet No. II.

"*East* Branch of the Susquehanna" should be, *West* Branch of the Susquehanna.

"Upper and Lower *Agusta* Townships" should be Upper and Lower *Augusta* Townships.

"Tama*u*qua" should be Tamaqua.

In section No. 1, the lowest coal bed is 8′ thick instead of 12′ thick; the total coal 22′ instead 26′; and the total thickness 325′ instead of 329′.

In section No. 3, the "I bed" should be the J bed.

Miscellaneous Sheet No. III.

The Nesquehoning R. R. tunnel at Lansford was opened in 1870 instead of 1872.

LETTER OF TRANSMITTAL.

To His Excellency Governor ROBERT E. PATTISON, *ex officio Chairman of the Board of Commissioners of the Second Geological Survey of Pennsylvania :*

SIR: With the greatest satisfaction, I have the honor of presenting to the Board of Commissioners Mr. Charles A. Ashburner's first report of progress of the Anthracite Survey, with its atlas of maps and sheets of sections, illustrating the geological structure of the eastern end of the Southern or Pottsville field, extending from Mauch Chunk to Tamaqua.

Three years have elapsed since the first steps were taken to set on foot this section of the Survey of the State; but the rate of its progress must not be measured by the long delay of the publication of this first report, which, important as it is, exhibits but a small part of the work accomplished in these three years and in various stages of preparation for publication.

Besides the 13 sheets of maps and sections accompanying this report, 2 others (Plates IV and V) will be found bound into the volume.

Of the Western Middle field 7 sheets are engraved, 7 engraving, and 3 ready for engraving.

Of the Eastern Middle or Lehigh field 11 are ready for engraving.

Of the Northern or Wilkes Barre field 12 are engraving, and 4 ready for engraving.

But even these 59 sheets do not represent the whole amount of work done during the last three years by the Anthracite corps under the direction of Mr. Ashburner. Other sheets are in various stages of preparation upon which the surface surveys and underground examinations, cross section calculations, and columnar section records, verified or to be verified, have been already delineated.

As the practical usefulness of the geological survey of the Anthracite region depends and will depend upon the minute accuracy of the maps and sections which it publishes, especially of its underground contoured maps, and its vertical cross sections, these have to be constructed slowly and carefully, revised again and again, submitted to every kind of intelligent and practical criticism, and supervised in the press at any expense of time and trouble. The patient industry of Mr. Ashburner and his whole corps has been equalled only by their unwearied zeal and their earnestness in overcoming the various kinds of obstacles which the nature of the work continually creates, sometimes in the most unexpected forms. But the final publication is mostly delayed by protracted and repeated proof-readings of the complicated mass of facts; by corrections, additions, and substitutions made necessary by circumstances connected with that stream of information which keeps pouring in to the different offices of the survey—a flood of detailed facts respecting every colliery and every tract in the region.

The sheets of *cross sections and columnar sections* prepared by this survey offer no new feature for remark. They are such as all geological surveys publish. All that need be said of them is that no geological survey has ever constructed such sheets from more copious data, or with more minute care; and the distinction is visible between what is certain and what is only probable or possible.

The sheets of *underground maps*, on the contrary, exhibit a feature to which I invite special attention. Although not entirely new, I am not aware that it has ever before characterized a whole suite of publications of any geological survey. Not a few single collieries and iron mines have been mapped in contours so as to show the plications of the mineral beds; but in this survey the whole Anthracite region will be so mapped; the levels running from colliery to colliery, underground, from one end of each basin or group of basins to the other. By this means the shapes of the rolls and overturns are exhibited, and means are afforded to mining engineers and superintendents for directing their headings with less anxiety respecting what is in advance of them.

The high value of this kind of information has been already generously acknowledged, and has produced a demand for single sheets as fast as they can be got through the press. So important are these underground contoured maps to those who direct the mines, that a certain number of each edition are sold separately as soon as printed, in rolls, instead of being folded for publication, so that the creasing of the paper may not interfere with the measurements of those who desire to use the sheets for plotting the progress of old workings and planning new ones.

If one will picture to himself a dozen copies of such an underground map sheet lying on the office tables of the collieries existing within its limits, consulted by everybody interested in these collieries, and in daily use by every one of their mining engineers and superintendents plotting instruments in hand—he will get a good idea of the necessity under which Mr. Ashburner and his corps continually live to anticipate this microscopic criticism by an extreme accuracy of observation, drawing, and proof-reading in the case of each sheet. I repeat that this involves not only great labor but great delay; and the greatest delay is caused by repeated corrections in engraving.

Respecting the *organization* and conduct of the survey described in Chapter I, I need only say that the credit of it belongs to Mr. Ashburner, to whose scientific and executive ability I am glad to have this opportunity of testifying.

The *nomenclature* of the Anthracite fields has always been a puzzle from the time the region was first systematically surveyed, in 1838–9, by the talented Assistant on the First Survey, Dr. James D. Whelpley. Professor Rogers adopted a different method from Dr. Whelpley's, but it has not been used. Mr. Ashburner employs well known local names for the different anticlinals and synclinals (rolls and basins) as described on page 23.

The *method of constructing cross sections* pursued by

Mr. Ashburner (see page 41) will be closely criticised by the mining engineers of the region; I am convinced that they will not only respect the conscientious carefulness, but more and more admire the scientific skill with which this part of the work has been done. I think that they cannot help feeling a considerable confidence in the *probability* of the construction wherever there is a lack of actual data. At all events many new and useful ideas will be contributed to the engineering science of the region.

The *identification of the coal beds* of one colliery or basin or district with those of another is a problem of much more than scientific interest; for, it affects the market value of a fuel mined whether it be called by the name of a bed in high repute like the old Diamond, or Primrose, the Mammoth, the Buck mountain, or the Lykens valley—or whether it be named as coming from a less known or less favorably known bed.

But Mr. Ashburner wisely postpones the classification of the coal measures as a whole, and confines his use of names to cases and places where they are absolutely approved. In every case of doubt the *local name* is used, so as not to produce trouble for the future. (See page 84.)

As the survey advances—as new underground connections are made—as borings and tunnels multiply—whatever general system really exists in nature touching the number and order of the coal beds, it will gradually make itself known; but, the knowledge acquired by half a century of mining the anthracite beds not only inspires a wholesome caution in asserting the identity of beds in each neighborhood, but suggests a deep distrust of all generalized sections hitherto made. If the Mammoth can spread its partings through two or three hundred feet of vertical range, as it is known to do west of Pottsville, we may well ask ourselves what confusions of the column are there which are not possible everywhere throughout the region.

The imprudence, or rather the uselessness of attempting at present a still larger identification of the whole column of coal measures at points even so near together as Pottsville, Shamokin, Hazelton, and Wilkes Barre—to say nothing of the identification of the anthracite column with that of the bituminous regions of the northern and western parts of the State—at least not until a thousand columnar sections all over the anthracite region have been verified and compared among themselves—is described and illustrated by Mr. Ashburner in Chapter IX, § 5, page 220. In the following pages, 222 to 239, he gives selected typical general *columnar sections* of the coal measures in various parts of the region, to show how impossible it is at present to recognize with certainty the different anthracite beds at different places; in other words, to follow any one bed over the whole region with a security against mistaking for it here and there some other bed overlying or underlying it.

To convince readers of this report that such assumed ignorance on this point is the actual outcome of our constantly increasing accurate knowledge of local facts, I may cite what the survey of the Panther creek basin has taught us respecting the extraordinary variability of the great Conglomerate at the base of the coal measures (see plate of columnar sections, No. III)—a variability which we will find repeated in the case of all the Conglomerate and sandstone intervals of the coal measures themselves when we get all our columnar sections made and verified. It was made known by the first survey forty-five years ago, that the great Conglomerate was 1,000 feet thick along the Sharp Mountain and only 400 or 300 feet thick in the middle and northern fields; but Mr. Ashburner's sections show a far more remarkable local variability at short distances, not across but lengthwise of the region; and everybody now is familiar with the fact that the great Lykens Valley bed near the bottom of the Conglomerate fades away and becomes one of the so-called "streaks" in the direction of the Lehigh river. If then such a bed inclosed within the well-defined limits of the Conglomerate cannot be identified with certainty as far north as Wilkes Barre, how rash we should be to yield to a demand of owners (say in Sullivan county) to pronounce a coal-bed there to be the Lykens Valley bed. What is true of this bed is more or less true of every other bed in the coal measures, not excepting even the Mammoth.

The model of the flexed floor of the Mammoth bed was made by Messrs. E. B. & O. B. Harden, on a scale of 800′ to 1″ (vertical and horizontal), photographed (reduced to one third) from various points of view and under various lights, and then a selected photograph drawn on stone by an artist in the establishment of Julius Bien & Co., N. Y.

Plate IV, although exhibiting the model distorted by being foreshortened, nevertheless serves the intention of illustrating to the eye the remarkable shapes of the sub-basins, and of the sharp, steep, and sometimes overturned anticlinals which separate them.

The most striking feature of the plication of the coal beds of this basin is its sharpness, the rarity of those soft and gentle curvatures which characterize the bituminous coal basins, a rigid plainness of the up and down slopes, suggestive of (1) a severe lateral compression in the jaws of a vice, and (2) a humid plasticity of the coal measures at the time of compression.

These features are equally well exhibited by the numerous cross-sections on the sheets of the Atlas.

It would advance structural geology a long step if we could get at the data for portraying equally well the shape of the whole *bottom* of the Conglomerate (No. XII). Hitherto, whenever transverse sections of the Palæozoic system were made deep enough beneath the surface to include the underlying red shale (XI), the plane of contact has been conceived as a series of simple and compound waves of such a shape that the curves of the synclinals were struck with a larger and those of the anticlinals with a smaller radius. But we have always been and still are ignorant for the most part of the true character of this contact plane.

If, when we know it better, it should turn out to be plicated as sharply as we know the contact planes at the top and above the top of the Conglomerate are, the fact would go far to prove that the Conglomerate itself was as humid and plastic as the coal measures when first compressed. It would also reinforce the opinion that no Palæozoic plication occurred until the close of the coal age; and, that it took place then at once, and for all.

Although our ignorance of the shape of the bottom plane of the Conglomerate is great, what little we do know about it is significant. It can be studied, more or less unsatisfactorily, at the summits of the spur mountains in which terminate the numerous coal basins of the region.

Along some miles of the western end of the Dauphin County coal basin the basal layers of the Conglomerate, which form the crest of the mountain, are tightly pinched like the Panther Creek Coal measures; and it is *possible* that such pinching obtains along the line of every sharp synclinal in the Pottsville basin. If this prove true, we shall have a partial explanation for such amazing *local variations in the thickness of the Conglomerate* as are exhibited by the vertical section from Tamaqua (where it is 1,700′) through Lansford (where it is 900′) to the Hackleberry tunnel (where it is again 1,550′ thick). For if *both top and bottom* planes of the Conglomerate are sharply plicated, it is evident that there must have been a universal shifting of all the materials of the formation, both in various directions, and in various degrees, commensurate with the irregular construction, imperfect parallelism, and diverse amplitude of the different folds.

In other words, as the local bulging of the coal beds, so well known to miners, is imitated in the shales and sandstone intervals, similar local bulgings of the Conglomerate must have taken place; and that on as much larger a scale as the Conglomerate (as a whole) excels the coal measure intervals. In the case of crush faults or bulges in coal beds the statification is naturally obscured or destroyed; but in the case of the shale and sand intervals the stratification is nearly or quite preserved; therefore, in the case of the Conglomerate the transaction would take in all place (or some) of the strata, without causing their mutual interference; the increase in thickness of the entire formation being measured by the sum of the increments in the several strata swollen by the operation.

It is of considerable importance that this view be discussed, and that a large amount of additional information on the subject be obtained, because of its bearing upon opinions more or less incorrect that the very variable thickness of Conglomerate has been caused by a previous extensive erosion of the Mauch Chunk Red Shale formation (No. XI) which underlies it; that valleys and hills of red shale were produced; and that when the Conglomerate deposit was made it was necessarily thickest in the valleys and thinnest on the ridges of red shale.

Now, scarcely a single trace of any such erosion of the red shale has ever been observed, and what erosion has been noticed is so local and very minute* that it must have taken place under water. Moreover no such erosion has been observed throughout the flat lying bituminous coal regions to any extent worth mentioning.

The variable thickness of the conglomerate, therefore, must be discussed on one of two hypotheses: either, 1, we must surmise extraordinary and unaccountable variations in the quantity of gravel and sand deposited on neighboring parts of the red shale sea bottom; or, 2, we must apply the mechanical law that the folding of a plastic mass shifts all parts of the mass to allow of its accommodation in a smaller space.

Of the second hypothesis I have said enough to present it fairly for geological examination; but respecting the first hypothesis something remains to be added to prevent misconception.

While rapid local fluctuations in the *original thickness* of the conglomerate formation seem to be inadmissible with our present amount of knowledge on the subject, the well-known fact remains unchanged, that this conglomerate formation has a pretty uniform normal thickness of 300′ throughout Pennsylvania, except in the Southern field of the Anthracite region—a comparatively narrow belt through Carbon, Schuylkill, and Dauphin counties. This belt, no doubt, formerly extended in an E. N. E. and W. S. W. direction towards the Delaware and Potomac rivers; of which we can now say nothing. But along the hundred miles between the Lehigh and the Susquehanna rivers where it

*One pretty little exhibition of it may be studied in Solomon's Gap south of Wilkes Barre.

has been spared to our observation, a sudden, rapid, and immense increase of the thickness of the conglomerate takes place, from north to south; not exactly across the belt from N. N. W. to S. S. E., but diagonally, from north-west to south-east, or perhaps from W. N. W. to E. S. E.

Some years ago I endeavored to restore the formation in plan by means of contour lines, each line representing an observed thickness of 300′, of 400′, of 500′, &c., up to 1,200′. With the imperfect and uncertain data at my command I found these contour lines to throw themselves in concentric curves of great radius, the center of radiation being in the far south-east, say at Trenton, N. J.

The conclusion seemed to me irresistible that an explanation of the increased thickness of the Conglomerate south-eastward must be sought for in a supposition of some shore line backed by extensive lands in that direction, far enough away to be beyond the Middle or Lower Palæozoic outcrops, and yet near enough to account for the suddenness of the increase of thickness within the belt of observation. But the present topography of the Atlantic border furnishes nothing for this purpose except the South Mountain range from Reading eastward and its continuation on a larger scale as the Highlands of New Jersey. But the now completed topographical map of the South Mountains between Reading and Easton* seems to prove very plainly, what I have long believed, that the Azoic core of this range was entirely covered by the Palæozoic sediments at the time of the deposit of the Pottsville Conglomerate.

But apart from this consideration the problem of the origin and method of deposit of the Conglomerate, regarded as continuous over a large part of the United States, can hardly be much affected by our inability to explain its abnormal thickness along the narrow belt of the Southern Anthracite coal field. All the more important then become Mr. Ashburner's new measurements of the Conglomerate along the Locust mountain, and the *possibility* (for the hypothesis has still to be tested by fresh facts) that its extraordinary variations proceed from the bulging of the

*Published in the Atlas to Report D^3, Vols. I and II, 1883.

whole formation, on a grand scale, when in a humid plastic state, at the time of the emergence of the continent and plication of the coal measures.

Mr. Ashburner's estimates of quantities of coal in place, mined out, wasted and marketed, in chapter V (commencing on page 107) are based (1) upon a long series of personal measurements in the mines, and a new method of applying the data thus obtained to the cross sections of the basin; and (2) upon figures freely placed at his disposal by the superintending authorities, with whom all his conclusions have been fully discussed. His method (described on page 109) has been criticised as too elaborate and difficult; but this seems to me less objectionable than the vagueness of the ordinary more off-hand method, which takes no account of overfolds and other disturbing elements, and assumes roughly an average for thickness and a percentage for dip. The real importance of such estimates, apart from gratifying a laudable curiosity, lies in the stimulus they give to inventions for reducing the relative proportion of *wasted* to *marketed* fuel; and in the indications they afford that mining companies are pursuing an improving policy.

One discovery of the survey, mentioned on page 181, should have its value set forth in the clearest light; for, experts at the mines have expressed the opinion that it will save to the general business of the State more than the Geological Survey has cost. So-called "bony" coal, thrown aside as unsalable, but shown to be first class coal and quite salable when broken into fine sizes, has now taken its proper place in the market.

The manuscript of this report was edited and the index prepared by Mr. Ashburner.

I remain, sir, yours respectfully,

J. P. LESLEY.

PHILADELPHIA, 1008 Clinton street, *Dec. 1, 1883.*

PREFATORY LETTER.

907 Walnut Street, Philadelphia,
November 1, 1883.

Professor J. P. Lesley, *State Geologist :*

Dear Sir: I have the honor to submit herewith, my first report of the progress of the Geological Survey in the Anthracite Coal-fields.

This report relates particularly to the geology of the Panther Creek basin, at the extreme eastern end of the Southern Anthracite Field, between Mauch Chunk, on the Lehigh River in Carbon County, and Tamaqua, on the Little Schuylkill River in Schuylkill County.

Thirteen (13) sheets of maps, sections, etc., to illustrate the report, are contained in an atlas entitled "Southern Anthracite Field Vol. I, AA."

Most of the manuscript was completed, and ready for the printer on the first of January, 1883, but various circumstances prevented its immediate publication.

The general plan adopted for the survey of the Anthracite District is explained in Chapter I. Although in the main it is the same as that originally proposed in November, 1880, many of the details connected with its practical execution have been modified, or changed, as the exigency of the work required.

Chapters II to VII contain a description of the geology and mines of the Panther Creek basin and chapters VIII and IX have special reference to the entire Anthracite Region.

Professor C. L. Doolittle, of Lehigh University, has contributed a valuable paper, published in appendix A, which contains a detailed statement of his observations and computations made in determining the longitude and latitude of Wilkes Barre and Pottsville respectively. In a second appendix, lettered B, is published a careful and original discussion of the Theory of Stadia Measurements, accompanied by Tables of Horizontal Distances and Differences of Level, for the Reduction of Stadia Field Observations, by assistant Arthur Winslow.

My principal object has been to make the results of the Survey practically useful to those directly interested in the exploration and exploitation of the anthracite fields ; and therefore the work in the field has been prosecuted under the constant review of those connected with or engaged in the mining of coal.

The policy of pushing the purely geological and mining work of the Survey at the outset, in order that practical men might see some results and be able to judge of their utility, not only to themselves, but to all having interests in the anthracite region, has proved a wise one. The publication (in advance of the report) of the 13 atlas sheets accompanying this report has already secured to the Survey the support of every one in the region, from the miner engaged in cutting coal in the mines, to the Presidents of the coal transportation companies, all of whom were unanimous in urging the appropriation which was made by the Legislature of 1883.

Geodetic Survey.

Should the Legislature of 1885 see proper to make appropriations for the continuance of the Anthracite Survey, provision should be made for a triangulation of at least a narrow north and south belt, by which our local surveys in the Northern, Eastern Middle, Western Middle, and Southern fields can be accurately and sufficiently connected.

When this survey was organized, two years ago, I urged the necessity for such a geodetic base to precede the making of detailed maps. As our survey advances we feel the need of such a base of connection, more and more. If we had absolutely fixed points in the various disconnected areas of which we get local maps, or in which we are doing local work, it would save time, trouble and money in the preparation of the Atlas Sheets. Sooner or later exact connections will have to be made between the different fields; but, the appropriation of 1883 was not sufficient to permit of this geodetic work, without seriously hindering the survey of the collieries above and under ground. At present we have only two points in the whole anthracite region fixed with accuracy and these we owe to the zealous labor of Professor C. L. Doolittle, of Lehigh University, who at my solicitation in June, 1881, and without pay for his services, established astronomically the latitude and longitude of a a point in Wilkes Barre and Pottsville respectively.

These points I have used in my linear surveys for coördinating other points in their neighborhood; but the process of linear surveys is no substitute for triangulation; and errors increase in proportion to the distance from the fixed starting-point. Nothing but a belt of secondary triangles carried across from Wilkes Barre to Pottsville will suffice to make the survey of the Anthracite region a complete whole, by connecting with scientific accuracy our detailed maps of the four divisions of the region.

Continuation of Anthracite Survey and Estimates.

As the continuation of the Anthracite Survey after January, 1885, when the work will stop if no additional appropriation is secured, and its ultimate completion are matters of concern to those who are directly or indirectly interested in the mining and transportation of anthracite, I must allude to the subject of estimates.

In November, 1882, I endeavored to make an estimate of the time required to complete it, on the supposition that the plan then pursued would be continued. Since then, however, the details of the work have been considerably modified by the demands made upon us to make our examinations more and more minute; the results of which are evident to all who examine our published and unpublished sheets. It is therefore impossible for me to estimate the amount of time required to get over the whole region. The intricacy of the geological structure increases as we advance into parts of the field which have been less explored

State Revenue from Direct Taxation on Anthracite and Bituminous Coal.

Revenue derived from the tax of 4 cents per ton on Anthracite Coal mined from March 22d, 1867, to January 1st, 1874, under act of Assembly approved March 22nd, 1867.

	1867.	1868.	1869.	1870.	1871.	1872.	1873.	Totals.
Hazleton R. R. Co.,	$4,056.55	$4,697.50	. .		. .		. . .	$8,754.05
Del. & Hudson Canal Co.,	31,024.80	61,852.32	$49,381.80	$78,569.04	$44,520.68	$91,480.12	$146,571.04	503,399.80
Penn'a Coal Co.,	23,375.96	41,735.16	42,801.08	48,768.68	32,669.08	57,419.96	49,066.80	295,836.72
Del., Lack. & Western R. R. Co.,	32,637.28	56,244.36	49,475.78	80,111.70	53,394.18	82,928.33	92,469.04	447,260.67
Union Coal Co.,	659.52	972.53	.	. .		.		1,632 05
Lehigh Coal & Nav. Co.,	11,182.48	17,725.31	5,477.96	22,949.97	22,894.20	42,634.16	33,086.44	155,950.52
Summit Branch R. R. Co.,	. . . . . .	9,206.71	4,873.20	13,950.92	4,272.44	9,873.78	10,681.96	52,859.01
Lehigh Valley R. R. Co.,	. . . . .	. . .	7,567.68	6,842.91	6,009.44	15,017.89	4,478.63	39,916.55
Totals,	$102,936.59	$192,433.89	$159,577.50	$251,193.22	$163,760.02	$299,354.24	$336,353.91	
Total amount of tax,								$1,505,609.37

Revenue derived from the tax of 3 cents per ton on Anthracite and Bituminous Coal, mined since January 1st, 1874, under act of Assembly passed and approved April 24th, 1874. The repeal of this tax was provided for by act approved June 7th, 1879.

	1874.	1875.	1876	1877.	1878.	1879.	1880.	1881.	1882.
Anthracite coal,	$146,909.35	$439,775.94	$424,114.15	$395,278.93	$412,439.03	$544,667.33	$665,259.62	$200,923.17	$85,977.97
Bituminous coal,	15,776.49	81,953.53	96,891.62	87,566.08	117,747.43	100,324.84	145,879.54	56,711.62	4,725.89
	$162,685.84	$521,729.47	$521,005.77	$482,845.01	$530,186.46	$644,992.17	$811,139.16	$257,634.79	$90,703.86

Total tax on Anthracite Coal, (82%,)	$3,315,345.49
" " " Bituminous Coal, (18%,)	707,577.04
Total,	$4,022,922.53
Grand total of tax received from the mining of Anthracite Coal,	*$4,820,954.86*

The above table does not include the tax derived indirectly from the anthracite coal trade.

than those already mapped. The practical usefulness of this survey can be justly estimated, only by those directly interested in the development of the Anthracite Region. But the most indifferent observer cannot fail to appreciate the important relation which anthracite bears to all the industrial and material interests of the whole State.

The mining of anthracite coal is the most important and largest mining industry in any one of the States; in fact, there are but two such industries in the United States which exceed it.

During 1882 the estimated value at the mines of Pennsylvania Anthracite was $70,556,094. The value at the mines of all bituminous coal mined in the United States was $76,076,487, and of all gold and silver combined, $79,-300,000.* During the year 1880 the United States census estimated that of all the capital invested in coal mining in the United States ($256,502,373) one third was invested in the mining of Pennsylvania anthracite.

The only direct tax which has ever been levied upon the mining of any mineral in Pennsylvania was that upon anthracite, and afterwards upon bituminous coal. The table on the opposite page, compiled from the Auditor General's Reports, shows that up to the end of the year 1882 there had been paid into the State Treasury by the miners of anthracite coal $4,820,954.86, and by the miners of bituminous coal, $707,577.04. This is but a small proportion of the revenue derived by the State from the mining of anthracite, as the tax paid upon coal lands, by coal transportation companies, and other industries whose extent depends upon the mining of anthracite, must be looked upon as revenue dependent upon the development of these fields.

Economy of Mining and Exhaustion of Fields.

The question of the economical mining of coal in special districts is one of practical concern. While that of the ultimate exhaustion of the coal fields may not be of much practical value at the present time, it is one which always

* Report on "Mineral Resources of the United States," 1883, by Mr. Albert Williams, Jr., U. S. Geological Survey.

elicits general interest, and which, in the future, is bound to be considered by those directly interested in the mining of coal, or by a government commission.

A number of demands have already been made upon the Survey for a solution of these problems, and the plan upon which the work is at present being prosecuted provides for their consideration. In the case of the Panther Creek basin, the amount of coal which has been left in the mines for supports, that which has been taken out of the mines and thrown upon the culm banks, and that which has been shipped to market, have all been carefully computed. (Page 176.) Estimates* have also been made as to the amount of coal which is still available, and the depth at which it will be found. (Pages 141, 168 and 169.)

While the facts and conclusions stated in the tables in Chapter VI (pages 126 to 177 inclusive) apply in a special sense to the Panther Creek basin, it is believed that they will be of value as affecting the economy of mining throughout the entire region, when a comparison, of all the details connected with the mining of coal in special localities, shall be made with those which are found to obtain in the Panther Creek region. Whether this investigation, which has been made with such minuteness in the Panther Creek valley, can be similarly pursued in other localities remains to be seen. An endeavor will be made, in any event, to obtain the most *reliable* data bearing upon the subject, and to draw the most *reliable* conclusions which it may be possible for any one to arrive at.

As to the ultimate exhaustion of special parts of the coal fields, or of the entire region, the Survey has at present no data upon which to base any conclusion which would be of practical value. I have never made an estimate as to the duration of the Anthracite Coal Fields, because the Geological Survey has not advanced sufficiently to enable me to do so. In fact the Panther Creek basin, which covers about one fortieth of the entire area of the field, is the only

*In making the necessary estimates for these investigations, and in computing the results, great credit is due to Mr. Frank A. Hill, who superintended many of the details.

locality where any measurements have been completed by the Survey as to the amount of coal taken out, or that which still remains to be mined.

Mr. P. W. Sheafer, who has probably given this subject more careful consideration than any one else, has named something less than 200 years as the time when the Anthracite Fields will be practically worked out. Mr. Sheafer has made a general statement that the field originally contained about 25,000,000,000 tons of coal. Up to January 1st, 1883, I have estimated that the total production amounted to 509,333,695 tons. It has been generally thought that but one-third of the coal contained in the area which has thus far been mined over in the *entire region* has been consumed as fuel*; so that up to last January, an area had been exhausted which originally contained about 1,500,000,000 tons; 23,500,000,000 tons remaining untouched. If this same proprotion of production to original content be applied to that which still remains, about 8,000,000,000 tons would represent the possible future production.

According to the Mine Inspectors' Report, there was produced last year 31,281,066 tons. If this production should remain constant for all future time, the field would be exhausted in a little over 250 years.

Such a conclusion is quite untenable, for our yearly production is rapidly increasing. In 1870, there was shipped from the region 16.182,191 tons, and in 1880, 23,437,242 tons. The abrupt exhaustion of the coal fields is a practical impossibility, nor is it reasonable to suppose that if, on an average, for every ton of coal won there are two lost, this will be the practice in future mining.

The Geological Survey has in its possession already many facts to throw light on this subject, but as it is hoped that the Survey will be completed before this question of ultimate exhaustion will become one of practical concern, it would be folly for me to make any statement now, as to how long our Pennsylvania anthracite will last.

*Less than one-third of the original contents of the exploited areas in the Panther Creek Valley has been consumed as fuel (page 176); on account of the difficulties of mining in that district, this pércentage (27 per cent) may be considered to be below the general average.

Composition and Fuel Value of Penna. Anthracites.

Since the Survey has commenced its examination in the Anthracite Fields, numerous requests have been made for chemical analyses of the different coals; not, so much to show the mineralogical characteristics of the bed, as the fuel constituents of their commercial product. On account of the limited appropriation to provide for the anthracite work, it has been impossible, at the outset, to undertake an investigation of all the problems, both of a practical and scientific character, which have suggested themselves, and which it will be necessary to consider, in order to render the Survey complete, and its results of the greatest value.

One of the questions, which is beset with the gravest difficulties, is that of the mineralogical and chemical study of the anthracite coals. This has to do with the origin of our Pennsylvania anthracite, which is still an open question. Although we have many facts to indicate its probable answer, I feel that it will be necessary for a very careful mineralogical and chemical investigation to be made before we can with any assurance approximate to a final solution. The chemical investigations of Mr. J. W. Thomas, Dr. Ernest Von Meyer, and Marsillay, of the characteristics of British and European coals, have thrown much light upon the questions of the formation of coal, the influence of the atmosphere upon its deterioration, and the character of the gases evolved from the coal in the mines. Such investigations are of interest and value as aids in determining the deterioration of market coal when subjected to atmospheric influences under varying conditions, and the proper and most economical ventilation of the mines, either to dilute or entirely remove the gases which affect, not only the health of miners in the inhalation of slightly impure air, but their safety in the prevention of explosions.

The analyses of American chemists of many of our anthracite coals show the liability of the coal beds, or portions of them, to change their constitution and character within very short intervals. This feature has been more prominently demonstrated by the analyses of Dr. Charles M. Cresson, made for the Phila. & Reading R. R. Co.

The governmental researches of Professor Johnson made in 1842 and those made a little over a year ago by Quartermaster General M. C. Meigs, U. S. A., prove wide differences in the effective fuel value of many of the Penna. anthracites, and clearly indicate the economy in the purchase of special coals; although at the present time the coal trade makes no reliable distinction between the coals which are shown to have such different evaporate capacities. The tests of Sheerer-Kestner, and C. Meunier-Dollfus, reported to the Société Industrielle de Mulhouse, and those of William Kent, of Pittsburg, are claimed by Mr. Kent to show that theoretical estimates of calorific power, based upon ultimate chemical analysis, might sometimes vary as much as 15 per cent from the results obtained by a direct calorimetric trial; but the estimate based upon analysis was always the lower of the two. It is also noticeable, that generally the greater the percentage of oxygen in the coal, the greater the difference between the experimental and calculated results. Mr. Kent claims that chemical analysis, and especially the ultimate analysis for total carbon, hydrogen, oxygen and nitrogen, is a valuable guide to the steaming power of coal when properly burned; although, the results of the tests of both Professor Johnson and General Meigs indicate a directly opposite conclusion.

These references certainly show the necessity for the Survey making a thorough investigation as to the constitution of coal contained in the anthracite beds. What would be the best plan to be pursued can not yet be determined, nor was it intended that the Survey should enter upon these problems at all, until the purely mapping and geological work in the region had progressed further than at present.

The consumers of American coals are beginning to realize the fact that the value of a coal, as an effective fuel, under varying conditions of consumption, is not solely dependent upon its physical characteristics or the locality from whence the coal is obtained.*

*A prominent anthracite operator related to me an incident which illustrates the prejudices of the trade in regard to the values of coals. This gentleman was operating a colliery in the Shamokin region, and had connection from his

Chemical Analyses of Penna. Anthracites.

During the past year demands have been made for chemical analyses of *market coals*, showing the proportion of fixed carbon, volatile matter, water, sulphur, phosphorus and ash; and although such analyses are probably among the least important which should be made, it was deemed advisable in the case of the coals of the Lehigh Coal and Navigation Co., mined from the Panther Creek Valley, where the purely geological and mining work of the Survey had been completed, that such market specimens should be collected and analyzed. These analyses are contained in Chapter VII of this Report, where special reference is made to them.

After the proof of this report had all been corrected and the index placed in the State Printer's hands for publication, *a special request* was made for similar analyses of coals in different parts of the field, which are accepted by the coal trade as being of similar constitution and value to the Panther Creek coals. In consequence coals were sampled from these collieries similarly to those from the Panther Creek Valley. These specimens have been analyzed by Mr. A. S. McCreath. (See Table No. 1, pages xxxiv and xxxv.)

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colliery with both the P. & R. R. R., which transported their coal down the Schuylkill Valley, and the L. V. R. R., which shipped their coal to market down the Lehigh River. A contract was made for regular shipments of coal from his colliery over the L. V. R. R. at a time when there was a discrimination of 50 cents between the Lehigh and Schuylkill coals in favor of the Lehigh; the coal trade generally understanding that Lehigh coal was coal shipped over the L. V. R. R., and Schuylkill coal, that shipped over the P. & R. R. R.

The L. V. lateral which took his coal to the main line of the road had to be closed for some days for repairs, and he was compelled, in consequence, to fill his orders by shipment over the P. & R. R. R. But a few days had elapsed before his consignee complained of receiving a very inferior Schuylkill coal, instead of the superior Lehigh coal which he had formerly received, and he was forced to make a rebate of 50 cents a ton on the coal which he had temporarily shipped over the P. & R. R. R.

It is gratifying to know that among the more *intelligent consumers* no difference is recognized between the coal transported through the Lehigh Valley, and that through the Schuylkill Valley. In fact several favorite brands of coal which cannot be excelled, are now shipped almost entirely down the Schuylkill Valley.

If the water, sulphur, and earthy impurities, classed under the head of ash, be disregarded in these analyses, and the fuel constituents be alone considered, the percentages of these which are fixed carbon and volatile hydrocarbon respectively are given in columns Nos. 12 and 13 of this table. The fuel ratio of each coal, or the carbon divided by the volatile (hydro-carbons) matter is given in column No. 14. This plan, of designating the relationship existing between the fuel constituents of coal, was used by Prof. Walter R. Johnson in his report on American coals made to the United States Government in 1844, and has been employed in the reports of the Second Geological Survey as a convenient method of classifying the analyses of Pennsylvania coals.

Specimen No. 1.

Collected from Hollenback shaft No. 2 at Wilkes Barre, Luzerne County, Northern Coal Field, October 10th, by Assistants Frank A. Hill and Arthur Winslow, assisted by Mr. Finney, outside superintendent. Lehigh and Wilkes Barre Coal Co., operators.

The Baltimore (Mammoth) bed is the only one which is regularly mined at present at this colliery. A gangway is being driven however in the Hillman bed. There is being mined daily from this colliery, at present, about 103 mine cars of coal, only 3 of which contain coal from the latter bed. The coal was sampled from the market cars, which were loaded ready for shipment, by the method described on page 178. The number of cars (32) from which the specimen was collected, and the character of the coal contained, was as follows:

From	4	market	cars	of	lump coal.		
"	5	"	"	"	steamer and broken coal.		
"	3	"	"	"	egg or No. 2		"
"	6	"	"	"	stove or No. 3		"
"	5	"	"	"	"	" 4	"
"	3	"	"	"	chestnut or No. 5		"
"	4	"	"	"	pea	" 6	"
"	2	"	"	"	buckwheat	" 7	"

TABLE No. I.

No. of specimens.	Name of Colliery and Coal Bed.	Chemical Analysis.							Physical Properties.		Percent'e of Constituents of Fuel.		
		Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.	Phosphorus	Total.	Color of Ash.	Specific gravity.	Fixed Carbon.	Volatile combustible matter.	Fuel ratio $\frac{C}{V.H\text{-}C.}$
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
	NORTHERN COAL FIELD.												
1	Hollenback Shaft, No. 2, at Wilkes Barre, Baltimore (E) bed,	2.494	4.342	83.967	.653	8.544	.010	100	Reddish-gray,	1.614	95.08	4.92	19.33
2	D. & H. C. Co.'s No. 5, at Plymouth, Cooper bed,	3.676	4.516	80.510	.734	10.564	.002	100	Gray,	1.566	94.69	5.31	17.83
3	D. & H. C. Co.'s No. 5, at Plymouth, Bennett bed,	4.092	4.283	85.329	.794	5.502	trace	100	Gray,	1.546	95.22	4.78	19.92
	EASTERN MIDDLE COAL FIELD.												
4	Jeddo Nos. 3 and 4, at Jeddo, Mammoth bed,	3.862	3.242	85.319	.533	7.044	.005	100	Cream,	1.647	96.34	3.66	26.32
5	Ebervale No. 2, at Ebervale, Mammoth bed,	4.132	3.346	85.409	.511	6 602	.011	100	Cream,	1.595	96.23	3.77	25.53
6	Coleraine Nos. 1 and 2, at Coleraine, Wharton bed,	3.728	2.750	86.916	.574	6.032	.001	100	Reddish-gray,	1.621	96.93	3.07	31.57
7	Coleraine Nos. 1 and 2, at Coleraine, Mammoth bed,	4.304	2.996	86.712	.448	5.540	.017	100	Cream,	1.587	96.66	3.34	28.94
8	Spring Mtn. No. 4, at Jeansville, Mammoth bed,	4.042	2.986	88 201	.387	4.384	.003	100	Cream,	1.651	96.73	3.27	29.58
9	Spring Mtn. No. 4, at Jeansville, Wharton bed,	3.756	3.376	84.727	.731	7.410	trace	100	Reddish-gray,	1.626	96.17	3.83	25.11
10	Spring Brook No. 5, at Yorktown, Mammoth bed,	4,254	2.846	86 258	.604	6.038	.029	100	Cream,	1.605	96.81	3.19	30.35
11	Spring Brook No. 5, at Yorktown, Wharton bed,	3.652	3.116	87.569	.451	5.212	.001	100	Light cream,	1.614	96.56	3.44	28.07
	WESTERN MIDDLE COAL FIELD.												
12	St. Nicholas, at St. Nicholas, Middle Split, Mammoth bed,	2.494	4.040	80.288	.604	12.574	.002	100	Cream,	1.677	95.21	4.79	19.87
13	St. Nicholas, at St. Nicholas, Bottom Split, Mammoth bed,	3.448	3.660	81.816	.798	10.278	.002	100	Reddish-gray,	1.662	95.72	4 28	22.36

14	St. Nicholas, at St. Nicholas, Buck Mtn. bed,	2.500	3.956	83.297	.511	9.736	.004	100	Cream,	1.654	95.47	4 53	21.08
15	Gilberton, at Gilberton, Seven-Foot bed,	3.410	3 978	80.868	.512	11.232	.003	100	Cream,	1.651	95.31	4.69	20.32
16	" " " Buck Mtn. bed,	3.584	3 942	82 026	.414	10.034	.004	100	Cream,	1.681	95.41	4.59	20 79
17	Draper, at Gilberton, Mammoth bed,	2.718	3.826	81 293	1 501	10.662	.018	100	Reddish-gray,	1.666	95.50	4 50	21.22
18	" " " Primrose bed,	3 530	3.696	80.805	.511	11.458	.002	100	" "	1.646	95.63	4 37	21.88
19	Turkey Run, at Shenandoah, Mammoth bed,	3.510	3.622	79.660	.534	12.624	.010	100	" "	1.654	95.65	4.35	21.99
20	Kohlnoor, at Shenandoah, Mammoth bed,	3.646	3 440	82.655	1.011	9.248	.018	100	" "	1.628	96.00	4.00	24.00
21	" " " Primrose bed,	3.550	3.736	82.376	.488	9.850	.005	100	" "	1.662	95 66	4.34	22.04
	SOUTHERN COAL FIELD. (Lehigh Coal and Navigation Co.'s collieries. Panther Creek Basin.)												
22*	No. 3 Mammoth bed, (E,)	3 036	4.367	85.729	1.018	5.850	....	100	Red, white specks,	1.578	95.15	4.85	19.62
23	" 3 Red Ash " (F,)	2.930	4.290	88.181	.556	4 043	....	100	Cream,	1.574	95.36	4.64	20.55
24	" 4 Mammoth " (D and E,)	3.106	4.270	84.442	.492	7.690	....	100	Light cream,	1 615	95.18	4 82	19.75
25	" 5 " " "	3 040	4 656	83 706	.542	8.056	....	100	Light cream,	1.620	94 73	5.27	17.98
26	" 6 " " "	3.656	3.990	86.703	.505	5.146	....	100	Cream,	1.615	95.60	4 40	21.73
27	" 6 Red Ash " (F,)	3 086	3.960	87.783	.455	4 716	....	100	Dark cream,	1.595	95 68	4.32	22.15
28	" 8 Mammoth " (D and E,)	3.320	3.713	86 611	.423	5.933	....	100	Cream,	1.623	95.88	4.12	23 27
29	" 10 " " "	2 743	4.247	81.511	.623	10.876	....	100	Gray,	1.675	95.05	4.95	19 20
30	" 11 " " (D(?) & E,)	2.706	4 684	77.986	.884	13.740	....	100	Reddish-gray,	1.688	94 33	5.67	16.64
31	" 10, Mammoth (D & E) Bony coal, No. 1†	2.733	3 933	83.115	.423	9.796	....	100	Cream,	1.661	95.48	4 52	21.13
32	" 10, " " Bony coal, No. 2,	3.033	4 053	84.173	1.428	7.313	....	100	Reddish-gray,	1.647	95.40	4 60	20 74
33	" 10 " " Bony coal, No. 3,	2 826	4 247	82 083	.458	10.386	...	100	White,	1.677	95 08	4 92	19.32

* Specimens Nos. 22 to 30 inclusive in this table, are the same as specimens Nos. 1 to 9 respectively, noted on pages 179 and 180. † See page 181.

Specimens Nos. 2 and 3.

Collected from D. & H. C. Co's. colliery No. 5, at Plymouth, Luzerne County, October 10th, by Assistants Hill and Winslow assisted by Mr. A. W. Vandling, outside boss. D. & H. C. Co., operators.

The two splits of the Baltimore bed, known respectively as the Cooper and Bennett, are mined at this colliery. At present about one-fifth of the coal shipped is mined from the Cooper bed and four-fifths from the Bennett bed. The Bennett bed is considered by the operators to be the superior coal, as a great deal of slate and bone are found in the coal from the Cooper bed. The difference between these two coals is clearly shown by the analyses. The Cooper coal contains 5 per cent. more ash than the Bennett, and nearly 5 per cent. less fixed carbon. The specimen from the Cooper coal bed (specimen No. 2) was collected from 12 mine cars coming from different parts of the mine, and that from the Bennett bed (specimen No. 3) from the same number of mine cars from different parts of the mine in that bed.

Specimen No. 4.

Collected from Jeddo Nos. 3 and 4, or Oakdale Nos. 1 and 2 collieries, at Jeddo in the Black Creek Basin, Luzerne County, Eastern Middle Coal Field, October 6th, by Assistant Winslow, assisted by Mr. C. E. Albright, junior, engineer and Mr. Ario Thompson, shipper. G. B. Markle & Co., operators.

The Mammoth bed is alone mined at these two collieries. The mine workings supplying the breakers are so intimately connected, and in reality form parts of one mine, that specimens were taken from loaded market cars at each breaker. The greatest shipments made from these collieries are in larger sizes; very little pea and buckwheat coal being sent to market.

The sample was taken from 37 loaded market cars as follows:

From 3 market cars of lump coal from Jeddo No. 3.
" 5 " " " broken " " " " 3.

From	4	market	cars of	egg	coal	from	Jeddo	No.	4.
"	14	"	" "	stove	"	"	"	"	3.
"	10	"	" "	chestnut	"	"	"	"	3.
"	1	"	" "	pea	"	"	"	"	4.

To the above were added 3 small shovelsfull of pea coal.

Specimen No. 5.

Collected from Ebervale No. 2 colliery, at Ebervale in the Black Creek basin, Luzerne County, Eastern Middle Coal Field. October 6th, by Assistant Winslow, assisted by Mr. J. D. Jones, superintendent. Ebervale Coal Co., operators.

All the coal shipped from this colliery is mined from the Mammoth bed. The samples were taken from 23 loaded market cars as follows:

From	4	market	cars of	lump	coal.
"	5	"	" "	broken	"
"	4	"	" "	egg	"
"	2	"	" "	stove	"
"	6	"	" "	chestnut	"
"	2	"	chutes of	pea	"

The Ebervale and Jeddo collieries adjoin one another, on the Union Improvement Co's property; the Ebervale Coal Co. and G. B. Markle & Co. being the respective lessees.

Specimens Nos. 6 and 7.

Collected from Coleraine Nos. 1 and 2 collieries and from the stripping at Coleraine in the Beaver Meadow basin, Carbon County, Eastern Middle Coal Field, October 8th, by Assistant Winslow and Mr. John Wear, mine boss. Wm. T. Carter & Co., operators.

Both the Mammoth and Wharton beds are worked at this colliery. The coal mined from both beds passes through one breaker and is mixed before being shipped to market. It is estimated that the colliery is at present shipping daily one fourth of its coal from the Mammoth bed and three-fourths from the Wharton bed. The Mammoth coal which is taken from the strippings is considered by the operators to be very poor coal. The specimen of Wharton (specimen

No. 6) coal was sampled from 6 mine cars from colliery No. 1 and from 4 mine cars from colliery No. 2. The specimen from the Mammoth bed (specimen No. 7) was sampled from 4 mine cars from colliery No. 2 and from 4 mine cars from the stripping.

Specimens Nos. 8 and 9.

Collected from Spring Mountain colliery No. 4 at Jeansville, in the Beaver Meadow basin, Luzerne County, Eastern Middle Coal Field, October 8th, by Assistant Winslow assisted by Mr. Wm. McFarlane, breaker boss. J. C. Haydon & Co., operators.

Both the Mammoth and Wharton coal beds are mined at this colliery, about four-fifths of the daily shipment being mined from the Wharton bed and one fifth from the Mammoth bed. The coals are not shipped to market separately, however, but are mixed in the market cars. The Wharton coal mined at colliery No. 1 is considered to be a harder and better coal than that mined from the same bed at colliery No. 4. The Mammoth coal (specimen No. 8) was sampled from 5 mine cars at breaker No. 4 and in addition 3 lumps were taken from a heap at the blacksmith's shop. The Wharton coal (specimen No. 9) was sampled from 10 mine cars at the same breaker.

Specimens Nos. 10 and 11.

Collected from Spring Brook colliery No. 5 at Yorktown, in the Beaver Meadow basin, Carbon County, Eastern Middle Coal Field, October 9th, by Assistant Winslow assisted by Stephen Cann, mine boss. George H. Myers & Co., operators.

Both the Mammoth and Wharton beds are mined at this colliery; the Mammoth bed producing about three-fourths and the Wharton bed about one-fourth of the daily shipment. About half of the Mammoth coal is at present taken from the inside workings, and the other half from the strippings; the latter coal being considered the poorer. All the Wharton coal is mined under cover The Mammoth coal (specimen No. 10) was sampled from 5 mine cars from the stripping workings and 3 mine cars from the covered workings, about an equal amount of coal being taken from each place. The Wharton coal (specimen No. 11) was sampled from 6 mine cars.

Specimens Nos. 12, 13, and 14.

Collected from St. Nicholas colliery, at St. Nicholas, Schuylkill County, Western Middle Coal Field, October 15th, by Assistants Wells and Winslow, assisted by Mr. William Sanerbrey, outside boss. Philadelphia and Reading Coal and Iron Co., operators.

The middle and bottom splits of the Mammoth coal bed, and the Buck Mountain coal bed, are worked at this colliery. At present there are being mined daily about two thirds of the shipments from the Buck Mountain bed, about one sixth from the middle split of the Mammoth, and about one sixth from the bottom split of the Mammoth. The middle split Mammoth coal (specimen No. 12) was sampled from 8 mine cars; the bottom split Mammoth coal (specimen No. 13) from 4 mine cars from the drift level, and the Buck Mountain coal (specimen No. 14) from 10 mine cars.

Specimens Nos. 15 and 16.

Collected from Gilberton colliery at Gilberton, Schuylkill County, Western Middle Coal Field, October 13, by Assistants Wells and Winslow, assisted by John W. Howell, inside mine boss. Philadelphia and Reading Coal and Iron Co., operators.

At this colliery the Buck Mountain and the Seven Foot coal beds are mined, the better coal being considered to come from the former bed. The coal from the Seven Foot bed is *shelly*. About two thirds of the daily shipment is mined from the Buck Mountain bed and one third from the Seven Foot bed. The Seven Foot coal (specimen No. 15) was sampled from 10 mine cars, and the Buck Mountain coal (specimen No. 16), from 6 mine cars.

Specimens Nos. 17 and 18.

Collected from Draper colliery at Gilberton, Schuylkill County, Western Middle Coal Field, October 15th, by Assistants Wells and Winslow. Draper Coal Co., operators.

At this colliery the Mammoth and Primrose beds are the principal ones mined; about two-thirds of the daily shipment is mined from the Mammoth bed, two-ninths from the Primrose bed, and one-ninth from the Holmes and Buck Mountain beds combined. As the Mammoth and Primrose beds supply the principal product of this colliery, they alone were sampled, the specimen from the former (specimen No. 17) being sampled from 8 mine cars, and that from the latter bed (specimen No. 18) from 7 mine cars.

Specimen No. 19.

Collected from Turkey Run colliery at Shenandoah, Schuylkill County, Western Middle Coal Field, October 13th, by Assistants Wells and Winslow, assisted by Mr. F. Reese, outside boss. P. and R. C. and I. Co., operators.

The Mammoth bed alone is worked at this colliery, about 500 tons being shipped daily. The specimen was sampled as follows:

From		market	chute	of	steamboat	coal.
"		"	"	"	broken	"
"	2	"	cars	"	egg	"
"	2	"	"	"	stove	"
"	2	"	"	"	small stove	"
"	2	"	"	"	chestnut	"
"	2	"	"	"	pea	"
"	4	"	"	"	buckwheat	"

Specimens Nos. 20 and 21.

Collected from Kohinoor colliery at Shenandoah, Schuylkill county, in the Western Middle Coal Field, October 12, by Assistants Wells and Winslow, assisted by John C. Glover, boss. R. Heckscher & Co., operators.

At this colliery both the Mammoth and Primrose beds are mined, and the coal from each is shipped from a separate breaker. The specimen of Mammoth coal (specimen No. 20) was sampled as follows:

From	1	market	car	of lump coal.
"	8	"	"	of steamboat coal.

From 1 market chute of broken coal.
" 1 " " of egg coal.
" 1 " " of stove coal.
" 1 " car of small stove coal.
" 3 " chutes of chestnut coal.
" 1 " " of pea coal.

The Primrose coal (specimen No. 21) was sampled as follows:

From 1 market car of lump coal.
" 3 " " small stove coal.
" 2 " " egg coal.
" 1 " " chestnut coal.
" 2 " " pea coal.
" 3 " " large stove coal.
" 1 " chute of broken coal.
" 1 " " of steamboat coal.

*Specimens Nos. 22 to 30 inclusive.**

Collected from the collieries of the Lehigh Coal and Navigation Company in the Panther Creek basin, Carbon and Schuylkill counties, Southern Coal Field, June 26 and 27, 1882, by Assistant Winslow, assisted by Mr. John C. Rutter, mining engineer. The individual specimens were sampled as follows:

Specimen No. 22, sampled from
3 mine cars from tunnel workings.
3 " " " shaft "

No. 23, sampled from
3 mine cars from slope workings.
5 " " " shaft "

No. 24, sampled from
3 market cars of egg coal.
8 " " " broken coal.
2 " " " lump coal.

No. 25, sampled from
3 market cars of lump coal.

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*Specimens Nos. 22 to 30 inclusive, referred to here, are the same as specimens Nos. 1 to 9 respectively noted on pages 179 and 180.

No. 25, 5 market cars of broken coal.
No. 26, sampled from
4 mine cars.
No. 27, sampled from
4 mine cars.
No. 28, sampled from
5 market cars of broken coal.
5 " " " egg "
No. 29, sampled from
4 market cars of buckwheat coal.
4 " " " pea "
4 " " " chestnut "
4 " " " stove "
4 " " " broken "
No. 30, sampled from
15 market cars of buckwheat coal.
7 " " " pea "
3 " " " broken "
Nos. 31, 32, and 33, (see page 181.)

As has already been stated, these specimens (1 to 21 inclusive) were sampled in the same way as the Panther Creek coals. The specimens were collected in all cases in the presence of the superintendent, engineer, or mine boss at each colliery. As it was desired to obtain the constitution of the market product, the specimens were collected from the market cars wherever it was possible to do so. In some instances where the coal shipped came from two beds, and was mixed in the market cars, specimens were taken from the mine cars, in order to make an analysis of the coal from each bed. In such cases special care was taken to sample the coal, so that it would represent a product of equal purity to that shipped from the breaker. It is possible, however, that the analyses of such specimens will show a smaller percentage of ash than if the coal could have been taken from the market cars, as it is impossible to include or exclude just the same proportion of slate or bony coal as might be found in the market product. Naturally the tendency in sampling would be to reject the pieces of poorer coal.

Mr. McCreath, in remarking on the analyses of these coals, says, "In nearly every case where the ash is high the sample indicated it by showing considerable slate, sometimes as small lenticular masses of slate in the coal, and sometimes by separate pieces of slate. In the case of specimen 17, whose analysis shows 1.5 per cent. of sulphur, a large proportion of the sulphur was contained in a single piece of slaty coal, which on being broken was found to be strongly impregnated with iron pyrites."

Although the analysis of this particular coal *may probably* show too much sulphur, I believe that the percentage of sulphur, shown in the analyses generally, is not above the average of that contained in the coal marketed from each colliery, for which the analyses have been made.

The analyses in table No. I have been grouped in the order of the geographical positions of the collieries from which the coals were obtained, from north to south. In No. II, page xliv, I have arranged them in the order of the fuel ratio of the individual coals, and, in addition, have added the percentage of ash in the specimen analysed, for convenient reference.

The amount of ash which many of these analyses show is, doubtless, due to an imperfect separation of the slate and poor coal from the better coal in the preparation of the market product. In many cases, I believe the percentage of ash could be reduced by the construction of better breaker machinery and a more careful handling of the coal. It is important to remember that the practical solution of such questions is dependent upon so many varying conditions, that it would be impossible to say that it would be economical, for all operators of anthracite coal, to adopt any standard of product, as far as the percentage of ash is concerned. If a trade can be found for a coal containing ten per cent of ash, it would certainly be unwise in any operator to adopt more expensive methods to reduce the ash in his coal to six per cent. without gaining an increase in profits. The coal trade, however, is becoming more discriminating every year in regard to the true fuel value of coals, and it is probably

TABLE No. II.

No. of specimen.	NAME OF COLLIERY AND COAL BED.	Fixed carbon.	Volatile combustible matter.	Fuel ratio. C./V. H-C.	Percentage of ash in specimen analysed.
6	Coleraine Nos 1 and 2, Wharton bed,	96.93	3.07	31.57	6.032
10	Spring Brook No. 5, Mammoth "	96 81	3.19	30.35	6.038
8	Spring Mountain No. 4, " "	96 73	3 27	29.58	4.384
7	Coleraine Nos. 1 and 2, " "	96.66	3.34	28.94	5.540
11	Spring Brook No. 5, Wharton "	96.56	3.44	28.07	5.212
4	Jeddo Nos. 3 and 4, Mammoth "	96.34	3.66	26.32	7.044
5	Ebervale No. 2, " "	96.23	3.77	25.53	6.602
9	Spring Mountain No. 4, Wharton "	96.17	3.83	25.11	7.410
20	Kohinoor, Mammoth "	96 00	4.00	24.00	9.248
28	L. C. & Nav. Co.'s No. 8, Mammoth bed,	95.88	4.12	23.27	5.933
13	St. Nicholas, Bot. split Mammoth bed,	95.72	4.28	22.36	10.278
27	L. C. & Nav. Co.'s No. 6, Red Ash (F) bed,	95.68	4.32	22.15	4.716
21	Kohinoor, Primrose bed, ...	95.66	4.34	22.04	9.850
19	Turkey Run, Mammoth bed, ...	95.65	4.35	21.99	12.624
18	Draper, Primrose "	95 63	4.37	21.88	11.458
26	L. C. & Nav. Co.'s No. 6, Mammoth bed	95.60	4.40	21.73	5.146
17	Draper, " "	95.50	4.50	21.22	10.662
14	St. Nicholas, Buck Mountain "	95.47	4.53	21.08	9.736
16	Gilberton, " " "	95.41	4.59	20.79	10.034
23	L. C. & Nav. Co.'s No. 3, Red Ash (F) bed, . . .	95.36	4.64	20.55	4.043
15	Gilberton, Seven Foot bed, .	95.31	4.69	20.32	11.232
3	D. & H. C. Co.'s No. 5, Bennett "	95.22	4.78	19.92	5.502
12	St. Nicholas, Middle split Mammoth bed, . . .	95.21	4.79	19.87	12.574
24	L. C. & Nav. Co.'s No. 4, Mammoth bed,	95.18	4.82	19.75	7.690
22	L. C. &. Nav. Co.'s No. 3, Mammoth bed,	95.15	4 85	19.62	5.850
1	Hollenback Shaft No. 2, Baltimore bed	95.08	4.92	19.33	8.544
29	L. C. & Nav. Co.'s No. 10, Mammoth "	95.05	4.95	19.20	10.876
25	" " " No. 5, " "	94.73	5.27	17.98	8.056
2	D. & H. C. Co.'s No. 5, Cooper "	94.69	5.31	17.83	10.564
30	L. C. & Nav. Co.'s No. 11, Mammoth "	94.33	5.67	16.64	13.740
31	L. C. & Nav. Co.'s No. 10, Bony coal No. 1, } Mammoth bed.	95.48	4.53	21.13	9.796
32	L. C. & Nav. Co.'s No. 10, Bony coal No. 2, } Mammoth bed.	95.40	4.60	20.74	7.313
33	L. C. & Nav. Co 's No. 10, Bony coal No. 3, } Mammoth bed.	95.08	4.92	19.32	10.386

In table No. III an average analyses has been computed of the coals from the individual beds in the different coal fields, and arranged in the order of their fuel ratios.

Table No. III.

Average of specimens, Nos.	Name of Coal Bed.	Name of Coal Field.	Chemical Analysis.						Specific gravity.	Percentage of Constituents of Fuel.		
			Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.		Fixed carbon.	Volatile combustible matter.	Fuel ratio $\frac{C.}{V. H.-C.}$
6, 9, & 11	Wharton, ...	Eastern Middle, . .	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
4, 5, 7, 8, & 10	Mammoth, ...	" " . .	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
18 & 21	Primrose, ...	Western Middle, . .	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
12,13,17,19, & 20	Mammoth, ...	" " . .	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
23 & 27	Primrose ? (F,) .	Southern, ...	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
14 & 16	Buck Mountain, .	Western Middle,	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
15	Seven Foot, . . .	" " . .	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
22,24,25,26,28,29 & 30,	Mammoth, ...	Southern, ...	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
1, 2, & 3	Mammoth, ...	Northern, ...	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00

not premature to call the attention of coal operators to what seems an unreasonably high percentage of ash in their product.

As has already been stated, the investigation, which has been made by the Survey, of the constitution of the anthracite coals is a very necessary preliminary one, but the results thus far attained are of comparatively limited importance to the coal trade. What is wanted is a measure of the evaporative capacity of the different coals which are marketed; and it is hoped that the resources of the Survey, sometime in the future, will permit of such an investigation being made.

Personal Acknowledgments.

The liberal support and generous assistance, which has been everywhere rendered us, by the executive officers, superintendents, engineers, and mine bosses of the anthracite companies, and by the individual operators and their employees, is worthy of note. Their names are too numerous to be mentioned here; credit is given in the report and atlas, in each case, for the information which they have furnished.

In the case of some of the larger coal companies no *personal* acknowledgment has been made in the report and atlas, of the assistance rendered, and of the information procured from the individual employees of these companies. In *all* such cases, an acknowldgement has been made solely in the name of the company, by the *special request* of the executive officer through whose authority the information has been obtained.

All of the assistants of the Anthracite Corps have shown an individual interest in the work and have been untiring in their industry and zeal in furthering my plans. Special reference should be made here to Messrs. A. W. Sheafer and Frank A. Hill who assisted me in the Panther Creek Survey, and to my secretary, Mr. Charles B. Scott, who read the proof of the report.

In closing this letter, I wish to acknowledge the hearty and cordial assistance which you have rendered me in the organization and conduct of the Anthracite Survey.

I remain, respectfully and obediently your servant,

CHAS. A. ASHBURNER.

FIRST REPORT OF THE PROGRESS

OF THE

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA

IN THE

ANTHRACITE DISTRICT.

By Chas. A. Ashburner.

SOUTHERN FIELD, PANTHER CREEK BASIN.

Chapter I.

1. Introduction; 2. Arrangement and Publication of Results; 3. Mine Sheets; 4. Cross Section Sheets; 5. Columnar Section Sheets; 6. Topographical Sheets; 7. Miscellaneous Sheets; 8. General Plan of Work.

1. Introduction.

In August, 1880, a reconnaissance of the Anthracite Coal Fields was ordered by the State Geologist, in accordance with a resolution of the Board of Commissioners that the special survey of that district should be commenced. After examining the methods adopted by the mining engineers for representing on maps and sections their surveys, and consulting with private operators and with the executive officers of the mining companies, I reported in the following November a method * for representing on a horizontal plane

*The plan of mapping proposed was briefly described in a paper which I read at the Philadelphia meeting of the American Institute of Mining Engineers, February, 1881, entitled "A New Method of Mapping the Anthracite Coal Fields of Pennsylvania," (Transactions, volume IX, page 506.)

all the mine workings of the region, on sheet maps arranged in series according to the principal geographical divisions. The first sheet* so constructed was published by order of the Board, as a specimen to invite criticism, among the illustrations of Mr. Franklin Platt's Report (A^2) on the "Causes, Kinds and Amount of Waste in Mining Anthracite," January, 1881.

In May, 1881, the Board being enabled by a new appropriation of the Legislature to enlarge their plan, so as to embrace a systematic and exhaustive examination of the region, I was instructed to organize the Anthracite Survey; and, to furnish for publication all available data of a geographical and geological nature, both on the surface and underground, to meet the demands for information which persons interested in the mining of anthracite would be likely to make upon the Survey. This plan provided for such work, other than that of mapping, which is a necessary accompaniment of a complete geological survey of the coal fields.

To make the work of practical value in coal-mining, it appeared necessary to devise some new way of mapping the *general structure* of the coal basins The mine maps of the region are so accurate and complete that it would be folly for any government survey to attempt, with the limited means at its disposal, to inform the individual operator or mine owner of any of those characteristic features of the worked areas of their coal beds which depend upon accurate mine surveys.†

It seemed evident that it would be useless for the State

* The area covered by this sheet was remapped, after July, 1881, in a much more detailed way. The new sheet will be published with Vol. I, Western Middle Coal Field.

† Next to the triangulation surveys made by the United States and several State governments, the mine surveys in the anthracite region are, without doubt, the *most accurate* of any of the extended surveys which have been made in America. I do not make this assertion without a thorough knowledge and appreciation of the other classes of work which have been done by the Government and by individuals in the United States.

The surveys are made with the vernier, and the State law requires them to be carried to the face of the gangways and breasts and plotted to a scale of 100 feet to 1 inch every 6 months.

to do any work which should not be, to a great extent, new and original and furnish information in the form of reports, maps and sections, which are not already extant, and which should have a direct bearing upon mining problems concerning the future exploitations* of the coal basins.

What is wanted are better and more accurate maps, and better and more accurate sections, both vertical and columnar, of the coal strata than those that are now within the reach of the public.†

It must be remembered that although the law requires the mine surveys to be accurately made and plotted, that these maps are on a very large scale, are only of individual collieries, are disconnected, and are not accessible to the general public. In some localities the mine-owners and operators deem it necessary to the protection of their business to retain many important and *general* geological facts, beyond the reach of operators mining in adjoining tracts. To collect, examine, systematize, and publish such valuable facts, without jeopardizing the interests of the individual mine-owners, which shall be of practical utility to all anthracite operators, and particularly those mining in the vicinity where special information has been obtained, it is necessary that the work should be done confidentially by disinterested parties. None can so well inspire the confi-

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* The word exploitation is used as meaning the productive working of the coal basins as distinguished from their exploration.

†About two months after the work was commenced it was judged advisable to publish a geological map of Schuylkill county, to accompany the maps, drawn to a scale of 2 miles to 1 inch, of the counties already completed. It was thought that a map of this small scale could be easily and sufficiently accurately constructed from the following maps: Professor Roger's Map of the Anthracite Coal fields, 1858; Map of the First and Second Anthracite Coal basins, published by the Philadelphia and Reading Railroad, 1879, and Strauch and Cochran's Map of the Anthracite Coal fields, 1879.

I reduced each one of these maps to a common scale of 2 miles to 1 inch, and upon reproducing each one on to one sheet, I was very much surprised to find that there was no agreement between the geological lines limiting the coal basins. Each one of these three maps is considered to be authoritative, as showing on a small scale the position of the coal basins, yet they all differ; in consequence I was obliged to abandon the construction of the county map.

I mention this fact in order to convey some idea of the accuracy of the *best maps* which are published.

dence of the mine-owners, and so well execute the work, as competent engineers and geologists employed by the State.

The demands which it seemed necessary to meet are as follows: First, to collect all the mining information concerning each colliery, such as the elevation of the coal outcrops, the dip and strike of the coal bed, the thickness of the bed and its stratigraphical relationships, the area which is exhausted and under exploitation, and any special details connected with the methods of mining:

Second, to represent the geological structure of the areas where the position of the beds is known, either by actual workings in the coal or through tunnels, shafts, and drill-holes:

Third, to represent the most probable structure of the areas not worked or unexplored:

Fourth, to estimate the amount of coal which has been taken out of individual collieries or basins, the amount which is still available by more economical mining in areas already worked, and the probable amount which is still contained in areas as yet untouched.

In order to classify these facts in the most practical way for ready reference and use, it seemed necessary to place them on maps whose scale should be sufficiently large that measurements might be taken directly from them.

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2. *Arrangement and Publication of Results.*

The results of the survey are to be classified and published on six different series of sheets, as follows:

1. Mine sheets, scale 800′=1″* ($\frac{1}{9600}$ nature).
2. Cross section sheets, scale 400′=1″ ($\frac{1}{4800}$ nature).
3. Columnar section sheets,
   Rock sections, scale 40′=1″ ($\frac{1}{480}$ nature).
   Coal bed sections, scale 10′=1″ ($\frac{1}{120}$ nature).
4. Topographical sheets, scale 1600′=1″† ($\frac{1}{19200}$ nature).

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* Feet are frequently designated by ′ (800′) and inches by ″ (1″) in this report.

†A smaller scale was adopted for the topographical sheets on account of the cost of publication

5. Miscellaneous sheets.

These sheets are to be of a uniform size of 32″×26″; space inside of the border line to measure $28\frac{3}{4}''\times23\frac{3}{4}''$. This size is awkwardly large for handling, and was only adopted from the fact that the illustrations could be more conveniently placed upon this size of sheet than any other, and in the end much less paper would be needed than if a smaller sheet had been used; thus saving to the State a large amount in the cost of publication. In order to prevent the scale of the illustrations being destroyed in publication—which is so often done—a uniform length and width to the space inside of the border line of each sheet was proposed. On the mine sheets this space is always to measure, in length, 23,000′ ground measure = $28\frac{3}{4}''$ map measure, and in width 19,000′ ground measure = $23\frac{3}{4}''$ map measure; on the topographical sheets, which are of half the scale of the mine sheets, the space will measure, in length, 46,000′ ($28\frac{3}{4}''$) and in width 38,000′ ($23\frac{3}{4}''$). In the case ofthe topographical map of the Panther Creek basin, accompanying this report, a modification was made in this plan, on account of the size of the contoured area.

The coal fields have been divided into sections, and, as the sheets illustrating the geology of each individual section are completed, they are to be printed and distributed to the public with a short descriptive report.* After the survey of the entire region is completed, the geological report of all the basins will be published in two volumes; one on *Descriptive Geology*, and the other on *Systematic Geology*. The preliminary reports published with the sheets will only contain facts relating directly to them, with such brief explanations as may be thought necessary to make the illustrations perfectly understood.

The report next following this will be Volume I, Western Middle Coal Field, which will contain maps and sections of the eastern half of the field between Delano and Ashland;

* The descriptive reports to be published with future issues of the anthracite sheets will probably not be as long as the Panther Creek report. In this report it seemed desirable to give a brief description of the general plans of the Anthracite Survey.

this latter report will be followed by Volume II of the same coal field which will relate to the western half; by three reports on the Northern Coal Field—Volume I. Shickshinny to Wilkes Barre; Volume II, Wilkes Barre to Scranton; Volume III, Scranton to Forest City Colliery; by one volume on the Eastern Middle (Lehigh) Coal Field, and probably by three volumes on the Southern Coal Field west of Tamaqua, making in all ten volumes of preliminary reports and two volumes of final reports, for the Anthracite Survey. The small accompanying page map (frontispiece) shows the progress of the work up to January 1st, 1883. No estimate has been made of the time required to complete the work, as it is impossible to anticipate the difficulties that may be met with, in districts where no work has yet been done. It has consumed two years to complete the survey of less than one third of the entire region. Some of the most difficult areas to be surveyed are in districts where no work has been done. The time required to publish the illustrations of the survey is such that it will probably require two years to edit the maps and reports of the Survey after the completion of the field work.

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3. Mine Sheets.

The first series, designated as mine sheets will contain maps of all the coal-basins drawn to a scale of 800 feet to 1 inch, ($\frac{1}{9600}$ nature,) each sheet to cover an area of 15.67 square miles. On these sheets will be represented:

Surface Features.

1. Railroads.
2. County roads.
3. Streams.
4. Outcrop of coal beds.
5. Limit of coal measures.
6. Towns, coal breakers, etc.
7. North and south meridian lines, and east and west parallel lines, 2000′ apart, will be drawn across the surface of

the mine sheets, as well as the topographical sheets. These lines will be found of great value in the practical use of the maps and have been found necessary to prevent the material on the maps from being contorted, both in the engraving and printing. The lines are to be drawn parallel and perpendicular to the true meridian. In the case of the Panther Creek sheets, however, they have been placed parallel and perpendicular to the magnetic meridian. At the time these sheets were constructed the Survey had not completed the observations for the determination of the magnetic variation, so that it could not be used in locating the true lines on these sheets. Rather than delay the publication the sheets were prepared as they are. The lines will be numbered continuously north and south, east and west, from initial points whose longitude and latitude are known relative to the Washington meridian and the equator, so that the absolute position of each mine and topographical sheet on the surface of the earth will be known; and the distance between any points on different sheets, however distant, may be readily determined by computation without scaling across the intermediate sheets.

In addition to this material, which may be classed as surface features, a uniform style of title and scale has been adopted for all the sheets. These are illustrated by the accompanying Panther Creek sheets.

Underground Features.

1. Contour curve lines of the most extensively developed coal bed in the individual districts, (Mammoth bed principally.) Contours 50 feet vertically apart.

2. Area worked out and area being worked of contoured bed.

3. Gangways, tunnels, drifts, airways, etc., driven in all the beds, to be represented by a conventional color and line for each bed.

A map containing these facts will be of the greatest value; it will show:

1. Area of coal basins.
2. The area of the individual beds worked out and being worked.
3. Area of the coal basins not worked.
4. The structure of the basins where mined, with their rate of rise and fall.
5. The most probable structure of the areas where no mining has been done.
6. From these facts and measurements made in the mines, the amount of coal which will be available at different depths may be estimated.

The hypotheses and generalizations will be distinctly stated as such, and will be boldly separated from the absolute facts.

This system of representing underground structure in sedimentary beds, was originated in America some twenty-five years ago by Professor Lesley. It was first employed by him in private reports for showing the geological structure of coal and iron properties. Professor Lesley has made constant use of the method wherever possible in his professional practice. Since the commencement of the Second Geological Survey, several such maps have been constructed for the exhibition of special structural features.

Mr. Benjamin Smith Lyman has constructed underground contours on several maps of his private American surveys, and more recently has introduced the same method into the imperial surveys of Japan.

Within the last two or three years Hon. Eckley B. Coxe has used such contours, to a limited extent, for the definition of local mine dips. The method has also been employed in a number of European surveys.

The first time the system has been used on an extensive scale in America, has been in the construction of the mining geological sheets of the anthracite coal field. The data which are available for constructing these maps are very extensive and very accurate. The method has been found to furnish the best means for interpreting the geological structure and the best way of representing it; so that, in this the demands of the geological investigator are satisfied. At the same time that this end is accomplished, the facts, relating to the structure of the coal bed in the mines and adjoining tracts, are best classified and placed in such a form as to be of practical use to the mine superintendent and engineer.

The information which a geological mining map constructed on this plan contains, relative to the coal bed which is contoured, may be classified under the following heads:

a. Elevation above tide of the coal outcrop.

b. Dip of the bed.

c. Strike of the bed.

d. Depth of the coal basins.

e. Rate of fall or rise of the basins along their axes.

f. Position of the synclinals and anticlinal crests in the coal bed.

g. Data from which a vertical cross section of the bed may be made at any point across the basins.

h. Data from which the absolute area of the coal bed may be obtained, and the amount of coal contained in any special surface area estimated.

a. In order to obtain the elevation of the outcrop at every point, it is necessary that the bed should be contoured on a topographical map of the surface, as a basis.

b. The horizontal distance between the contour curves represents the cosine of the angle of dip.

To avoid overloading the map the degree of dip is not recorded in figures. The degree may, however, be readily determined by reference to the table given on the mine sheets, in which the relation is shown existing between the distance between the contour curves, to a scale of 800 feet to 1 inch and the degree of dip of the coal bed.

c. The direction of the contour curves shows the strike of the bed and the direction of the gangways which have already been driven or the most probable direction which approximately level gangways will assume if driven beyond the present mined area.

d. The most probable depth of the coal basins can be better estimated by this method of construction than by any other.

After all possible facts are obtained by prospecting, through surface diggings, shafts and drill holes, it is very important to classify them, in order to ascertain the depth of the basins for the proper location of shafts and slopes from which to mine the coal. This is admirably illustrated by the Panther Creek mine sheets. There are large areas in the center of this coal field where no mining has been done, but where the beds must ultimately be worked from deep shafts. It would be presumption to claim that the structure of the Mammoth bed in this basin will be found to be *exactly* as represented by the underground contours; but the structure is defined by them, as accurately and as minutely as it is possible to do with the present facts which are available.

e. The rate of rise and fall of the basins along their axes is a very important fact to determine, in order to locate mining works for the exploitation of the deepest portions of the basins; and more particularly, to establish the best elevation at which to drive gangways to command the greatest area of coal, with the least expenditure for the driving of permanent traveling ways and the lifting of the coal and pumping of the mine-water.

f. It is a well known fact, to the practical mining geologist, that the position of the crest of an anticlinal in a coal bed is not in the same vertical plane as the anticlinal axis of the overlying and outcropping strata. Where the dip on both sides of the anticlinal is the same, this necessarily follows: where the axial plane of the anticlinal is inclined, the axis in the outcropping strata may be many feet to one side or the other of a vertical plane, passing through the axis in the coal bed. The distance depends upon the inclination of the anticlinal, and the depth of the coal bed below the surface. This fact is illustrated by sections of the Panther Creek basin, (See Cross section sheets Nos. I, II, and III.)

g. It is apparent that a vertical section of the contoured coal bed may be constructed directly from the curves, running across the basin in any direction. The position on the section plane of the overlying and underlying strata may be located from columnar sections.

h. One of the most important applications of this method of construction, is the estimation of the absolute areas of the coal beds under any given tract, and consequently the coal contained. It is readily perceived that, when the contoured surface of the bed is developed or ironed out into a horizontal plane, allowance will have been made for every degree of dip which the bed possesses in its true position, and the real area of the bed on the flat will be shown.

Special reference is made to this in the description of Miscellaneous Sheet No. I (See Chapter V.)

In constructing the contour curves along the floor of the coal bed (Mammoth bed principally), the contours in those areas where the bed has been mined are first drawn. Where the elevations through the mines are sufficiently numerous, these contours show the absolute structure of the bed as proved by mining it. The structure thus defined is of interest to the general student, but of comparatively little practical value to the miner in illustrating the structure of the mined bed, since the workings in the bed have already given him, in a more practical way, the structure which the map defines. It must, however, aid him in extending his workings into new territory; and, where two or more coal beds are contoured, one above the other, the map enables him to determine quickly the thickness of rock between any two beds and the direction of thickening or thinning; this is particularly of value where the beds have flat dips and are close together.

In the second class of areas where there are no workings in the bed which is to be contoured, the contour curves are constructed from surveys made in the mines in beds underlying or overlying the contoured bed. The position of the contours in these areas is determined from a study in cross-section of the shape of the underlying and overlying beds. The structure of the contoured bed, which is thus defined, is of great practical value to the miner, if it is correctly solved. The correctness of the solution depends upon the accuracy of the cross sections, which are mostly made on the supposition that the different beds are parallel The Survey is obtaining innumerable sections in the different districts, which prove beyond a doubt that the coal beds themselves, and the intervals between them, thicken and thin within narrow limits. In fact, instances might be named where both coal bed and rock stratum double their thickness within short distances. Although such instances are numerous, they may be considered as exceptions and not the rule. While there are few facts to warn the miner or geologist of this occurrence, the experienced mining geologist, before constructing vertical cross sections, will consider the possibility of the interval between the beds thickening or thinning; and, if he correctly understands the features of the general structure, can frequently locate the areas where it is probable such instances occur.

The third class of areas in which the floor of the coal bed has been contoured are those where there are no mines either in the bed contoured or in those underlying or overlying it, and where but few facts can be obtained from surveys and examinations to enable the geologist to determine the structure. In these areas such facts as it has been possible to obtain have been carefully studied, and cross sections have been made, which, although hypothetical, may be accepted as embodying all information which can be obtained on this subject, and as representing the structure as correctly as it is possible to do.

From the way in which the maps are constructed these three areas are clearly defined. The structure of the first none can question; that of the last two any one can modify to agree with his individual views, after a resurvey of the facts which we have represented, or from incorporating other facts which we have not obtained.

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4. Cross Section Sheets.

The mine maps are to be supplemented by sections across the coal basins, to show the same structure on a vertical plane that the mine maps show by their contours on a horizontal plane. These sections are to be drawn on a scale of 400 feet=1 inch, ($\frac{1}{4800}$ nature.) No special plan, either in the distances of the cross sections apart, or the method of representing the structure which they will illustrate, can be adopted for the entire region. The frequency of the sections in any basin must be governed entirely by the difficulties in the structure to be solved, and the number of facts which it is possible to obtain.

In the Panther Creek region 12 general sections across the basin were constructed, varying in distance apart from 1550′ to 9100′. In the case of the Nesquehoning workings the sections were more frequent, not only because the structure was more difficult than elsewhere, but because more facts have been obtained from mining in the center of the basins than to the west, where the sections were placed further apart; here the structure of the coal beds in the center of the basins may ultimately be proved by mining to be as complicated as at Nesquehoning. There are reasons, however, which will be stated in the final report, which lead me to suspect that this will not be found to be the case.

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5. *Columnar Section Sheets.*

These sheets are to contain columnar sections of the coal measures and coal beds, to show graphically the character and vertical thickness of the strata included between the coal beds and the divisions and character of the individual beds with the intercalated slate and sandstone. They will be divided into two sets: First, those containing the rock sections, which are within the limits of the productive coal measures, to be drawn to a scale of 40′=1″; in these sections, the entire series of strata popularly known as a coal bed, whether coal or refuse, will be printed solid black and designated as coal; the rock sections, which are below the limit of the productive coals, will be drawn to a scale of 100′=1″. This latter scale (100′=1″) is that which has been universally used in the publication of the bituminous coal measure sections in all the survey reports. In the case of the anthracite sections, where the character of the strata between the coals has been recorded with greater care, and where the sections are of more practical value in mining, it was necessary to adopt a larger scale, in order to show by a system of line shading all the details of the stratification. The scale of 40′=1″ was adopted, as it was thought it could be more readily referred to with the ordinary foot and inch scale which is used in all measurements throughout the region; in the case of a pocket rule as ordinarily divided, 10′ would be equivalent to ¼″. The second class of sheets will contain coal bed sections to be drawn to a scale of 10′=1″. In these sections the alternations of good coal and poor coal, of sandstone, slate, bone and dirt, will be shown with as much minuteness as is actually found in the bed, in the mine.

From a study and comparison of these sections, after they shall be placed in vertical columns, the beds can be best identified. The proper identification of the coal beds will be one of the most important results to be derived from a geological survey of the anthracite coal basins. Some of the inconsistencies which at present exist are shown in the sections accompanying the general map of the coal fields (Miscellaneous sheet, No. II). Special reference is made to these sections in the descriptive notes, relating to this map, in the latter part of the report.

In addition to these three groups of sections to be constructed to scales of 40′, 100′, and 10′ to 1″ respectively, diagrams of sections to illustrate special features constructed to varying scales will be placed on the columnar section sheets. The necessity for this is shown by the diagrams contained on the Panther Creek sheets Nos. II and III.

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6. *Topographical Sheets.*

Surface contour curve maps will be published of most of the coal basin areas. These maps will be on a scale of 1600′=1″. or one half the scale of the mine sheets. The topographical sheets will be covered by a system of north and south, and east and west block lines, drawn 2000′ apart, which will correspond in their relative positions, with those similarly placed on the mine sheets. The area covered by one of these blocks on the topographical sheet being equivalent to the area covered by a corresponding block on the mine sheet. The relation of the geological structure of the coal beds to the surface topography, particularly that of the bed contoured, would be more clearly defined by placing the contours of the surface directly over the map of the underground features. In the case of the coal basins, where surface contour maps have been constructed, which have been placed at the disposal of the Survey, and which the law creating the Geological Survey compels the Board to publish, it has been found impossible to do this. The topographical maps, which have come into the possession of the Survey, have not been found sufficiently accurate, to make it possible to combine them in this way with the mine sheets constructed by the Survey corps, without completely revising them on the ground. As the restricted means of the Survey have prevented this revision, it was decided to publish these maps separately, and on one half the scale of the mine sheets, in order to reduce the cost of publication. This difference of scales makes a comparison of the two sets of sheets inconvenient.

Before the completion of the Geological Survey of the Anthracite Fields, it is hoped that surface contour curve maps may be constructed by the corps of the following areas :

1. Northern Coal Field, north-east of Scranton, to supplement that south-west of Scranton, constructed by Mr. R. P. Rothwell.

2. Eastern Middle Coal Field.

3. Western Middle Coal Field, west of Mount Carmel, to supplement that east of Mount Carmel, constructed for the Lehigh Valley Railroad, by Messrs. Stephen and Joseph S. Harris and A. J. Womelsdorf.

4. Southern Coal Field, west of Tamaqua.

In some of these areas the contours of the surface can no doubt be placed to advantage on the mine sheets, without overloading the map to such an extent as to produce confusion.

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7. *Miscellaneous Sheets.*

The principal material to be placed on these sheets will probably be the graphical development of the surface of the coal beds into horizontal planes, as a means of estimating the areas of the beds under exploitation, not mined, and the approximate tonnage of the coal still remaining. This method is specially described in the explanation of Miscellaneous sheet No. I of this report. Other illustrations besides those to be placed on the four series of sheets just noted will be placed on the miscellaneous sheets.

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8. *General plan of work.*

The general plan of work adopted, is practically the same in all the districts which have as yet been occupied; and the general method of classifying and of representing the results of the Survey, will be everywhere the same. The details of the work and of the method of representation, however, have to be greatly modified to suit special conditions and circumstances connected, both with the mining of coal and the plan pursued by the operators in the different districts, of recording their surveys and the geological facts which they have noted. For instance, everywhere in the coal regions, the operator has maps of his mines showing the workings, constructed on a scale of 100′=1,″ which maps are supposed to be brought up to date every six months. This is one of the conditions of the laws on the subject, and the operator is forced to its compliance by the Mine Inspectors. Beyond this, there is no law or custom which controls the recording or graphical representation of any other facts, which the operator may obtain in the course of mining. The greatest difference exists in making surveys of the levels in the mines. Through the Eastern Middle, Western Middle, and Southern Coal Fields accurate level surveys of the mines have been made, and in most cases, the elevations are referred to a common datum, that of mean high tide being the one generally accepted. In the Northern Coal Field, there are comparatively few of the mines which have ever had any level surveys made of them. Of the sixty collieries which the Survey corps have already (January 1, 1883) mapped in this basin, west of Enterprise colliery, twenty-nine have had levels run through their workings, eighteen have had partial levels taken at special points, and thirteen have had no levels.

In the Western Middle Coal Field most of the 100′ maps of the mines have been reduced, by the resident engineers, to large connected maps constructed on a scale of 300′=1″. In this district also, a great many cross sections of the basins have been constructed. In the Lehigh region there are, with but one or two exceptions, no complete maps of the mines on a scale less than 100′=1,″ and but few cross sections of the basins, as compared with the number in the Western Middle Coal Field. Here, however, on account of the narrowness of the basins, many of the 100′ maps have been placed on one connected map, which in some cases extends the entire length of the basin.

In the Northern Coal Field no general system has been adopted in the construction of maps of the mines on a scale less than 100′=1″. Some of the companies have a connected map on a reduced scale (200′, 300′, or 400′=1″) of their own mines; but these maps do not show, as a rule, the connection of the mines which they control, with those on adjoining properties. Where such a connection has been shown, we have generally found it to be incorrect, and have been obliged to establish a new connection from a replotting of the facts represented on the independent 100′ maps of the two companies, or from lines run in the field. But few cross sections have been constructed showing the structure of the Northern basins. If mine levels and cross sections are of any practical value as aids to the proper and economical mining of anthracite coal—as I believe they are—I know of no basin in the coal region where they would be of greater assistance than in the Wyoming and Lackawanna regions.

These differences make the details of the work in the Pottsville, Hazleton, and Wilkes Barre offices quite different. The general plan of doing the work of the Survey has been, to first construct general mine maps and cross sections by collating and systematizing all the facts which it has been possible to obtain from existing records. These facts are then supplemented by field work of the Survey corps, which is found necessary to clear up inconsistencies in the records thus obtained, and to make the maps and sections reasonably complete. The corps have been required to do much more field work than was at first expected. Although the surveys and maps of the territory which is at present being worked are accurate and complete, there are large areas, between the individual mines and along the edges of the basins, of which no careful surveys have been made. In such cases, it has been necessary, not only to make instrumental surveys to obtain a basis for the new maps and sections, but to make careful and minute geological explorations, both inside of the mines next adjoining these unsurveyed areas, and outside over the areas themselves. Where this has been done, in some territories whose geology has been supposed to be thoroughly understood, we have found, after collating all the facts which it has been possible to obtain from different sources, some of the greatest inconsistencies in the results indicated. These surveys are not made, however, until everyone who knows anything about the questions involved has been interviewed. In this way a duplication of facts is prevented. In some instances, some of the finished mine maps and vertical cross sections, which have been furnished the Survey by the operating companies, and which it was supposed could be taken as authoritative, just as they were copied, have afterwards had to be reconstructed in the Survey offices. The amount of information which, by degrees, is coming into the possession of the Survey is so great, that in many cases, facts are obtained which have a direct bearing upon the geology shown on the maps and sections constructed by parties who have never possessed much of the information in the hands of the Survey corps. After the partial completion of the mine and cross section sheets in this way, a personal examination is made in the mine of the geological difficulties which have been encountered in the colliery workings. During this examination, sections of the coal beds will be measured, wherever it is deemed necessary, to supplement those already measured by and obtained from the resident engineers. The columnar sections are then constructed and arranged upon sheets for publication. The facts procured in this personal examination in the mines, will form a basis for the estimation of (1) the amount of coal which was originally contained in the area under exploitation ; (2) the amount which has been taken out of this area, and, (3,) consequently, that which still remains. Of this latter amount, it is proposed, as in the case of the Panther Creek mines, to estimate (4) that which can still be removed, and (5) that which must remain, either as a permanent support to the superincumbent strata, or to insure temporary support while further mining is being carried on. The estimates for the Panther Creek mines are given in Chapter VI.

The primary object of the Survey being the solution and representation of the geological structure of the coal fields, only such surface topographical surveys are made by the Survey corps as are necessary aids to the accomplishment of this object, and as are needed to supplement and complete the many topographical maps which have been constructed by the mining engineers in the region, and which everywhere have been placed at the disposal of the Survey.

The illustrations necessary to supplement those contained on the mine, cross section, columnar section, and topographical sheets are then made, and the material placed in the hands of the Superintendent of Public Printing for publication. Final proofs of these sheets are obtained, for the different districts into which the region will be divided to be reported on, and examined by those who have furnished facts to aid in their construction; after this a preliminary and descriptive report is written by the Geologist in Charge, when the published results of the Survey are available to the public.*

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* On account of the slow progress of the work, both with the Survey corps, and in the printer's hands, due to the minute details which are considered and represented on the sheets, it is absolutely impossible to have the different series of sheets, to be contained in any one atlas, finished about the same time. Past experience has shown that it requires about one year to engrave and print the mine sheets, after the originals have been completed in the Survey office. It is not practical to commence printing the section sheets until proofs have been received of the mine sheets; so that, in most cases, a complete atlas will not be available to the public until about two years after the survey of the area which it covers has been practically finished. To meet this difficulty, the Board of Commissioners, at a recent meeting, decided to place a limited number of the single sheets on sale as soon as each shall be printed, to meet more particularly the local demand. The single sheets can be purchased by addressing Mr. Wm. A. Ingham, Secretary of the Board of Commissioners, 907 Walnut street, Philadelphia.

Chapter II.

1. Panther Creek Mine Sheets; 2. Basins and Anticlinals; 3. Locust Mountain Basin; 4. Hell Kitchen Anticlinal; 5. Hell Kitchen Basin; 6. Rhume Run Overturned Anticlinal; 7. Greenwood Basin; 8. Shaft Anticlinal; 9. Lansford Basins; 10. Coaldale Anticlinal; 11. Bull Run Basin; 12. Summit Hill Anticlinal; 13. Summit Hill Basin; 14. Dry Hollow Anticlinal; 15. Dry Hollow, Tamaqua, and Sharp Mountain Basins; 16. Deepening of the Panther Creek Basins; 17. Tidal Elevations.

1. Panther Creek Mine Sheets.

The mine sheets were originally constructed on a scale of 400′=1″ and were afterwards reduced by photography to the scale of publication, 800′=1″. The surface and mine surveys of the Panther Creek basin, made by the Lehigh Coal and Navigation Company have been plotted as the law requires, on a scale of 100′=1″. These maps, between Hacklebarney tunnel and Tamaqua, were reduced by Mr. R. W. Symons on to one connected map, on a scale of 400′=1″. This reduced map was used in conjunction with the original maps as a base for the mine sheets. Much additional material was added to this map from the surveys of the Nesquehoning, Switchback, Lehigh and Susquehanna and Lehigh Valley railroads, and from the field work done by the Geological Survey.

The block lines drawn across the face of the sheets are 2000′ apart and are parallel and perpendicular to the magnetic meridian of 1869. This meridian was adopted, as it is the one to which all the company's surveys are referred, and up to the time that the sheets were placed in the printer's hands no observations had been completed by the Geological Survey, to establish the true meridian.

In August and September, 1881, Prof. C. L. Doolittle determined the longitude and latitude of the Pottsville and Wilkes Barre Court Houses and established the true meridian in each locality. The results were as follows:*

Latitude Pottsville Court House, ...	40° 41′ 10″
Longitude Pottsville Court House, east of Washington, .	51′ 10.6″
Latitude Wilkes Barre Court House.	41° 14′ 40″
Longitude Wilkes Barre Court House, east of Washington,	1° 10′ 3.6″

In January, 1882, the average variation of the magnetic meridian, from the true meridian established by Prof. Doolittle at Pottsville, was determined, from twelve independent observations made by Assistants Sheafer and Wells, and found to be 5° 52′ west. In 1869 Mr. Richard P. Rothwell located the true meridian at Lansford and found the magnetic variation to be 5° 45′ west. This latter is the variation recorded on the mine sheets.

The magnetic variation at Wilkes Barre was determined by Mr. Frank A. Hill in April, 1882, to be 6° 30′ west.

The method used in constructing the contour curves along the floor of the Mammoth (E) bed is referred to in the description of the cross sections.

The general features of the mine workings shown on the mine sheets are briefly referred to in Chapter VI, where tables showing estimates relating to the production of coal from each colliery are given.

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2. *Basins and Anticlinals of the Panther Creek Valley.*

The system which has been adopted by the present Survey, of designating anticlinals in the coal measures, is substantially the same as that which was pursued originally by the first State Survey. The general plan adopted by Prof. Rogers was to make use of the name of "a village or colliery; and where greater precision was demanded, they were designated by some well known seam of coal arching across them; also, for the sake of still greater precision, by letters. Still better to classify them, the leading anticlinals

*See Prof. Doolittle's report, Appendix A. The exact position of the points from which the observations were taken are described in the Appendix.

were designated by capital letters only, the lesser ones by small type."*

This same plan of naming has been similarly applied to synclinal flexures or basins. The first Survey named synclinals from the anticlinal flexures which confined them. The marginal basins of the coal fields were named from the bounding anticlinal or monoclinal. This was an unfortunate classification, and was never generally accepted, from the fact that where the basins were broad, and their centers far removed from the axes of the bounding anticlinals, the connection between the two was difficult to retain, in consequence the basins have come to be more generally known by some geographical name, as in the case of the anticlinals. The use of letters to designate flexures in the strata has never proved popular in Pennsylvania. Although letters have been frequently used for this purpose, yet it is seldom that we find them referred to in the field, or in conversation, as a means of defining either anticlinals or basins.

In the Panther Creek basin, names have been adopted for the subordinate basins and anticlinals by using the name of a village or colliery, or a topographical feature which is well known and located directly over the basin or anticlinal. No difficulty should be experienced, by a careful observer of the mine and cross section sheets, in tracing these individual anticlinals and basins from one end of the district to the other. It is important to note here, that the flexures are not parallel with the main direction of the valley included between Locust Mountain on the north and Sharp Mountain on the south, but, in going from the eastern end of the valley west towards Tamaqua, they gradually approach the Locust Mountain or northern side of the valley.

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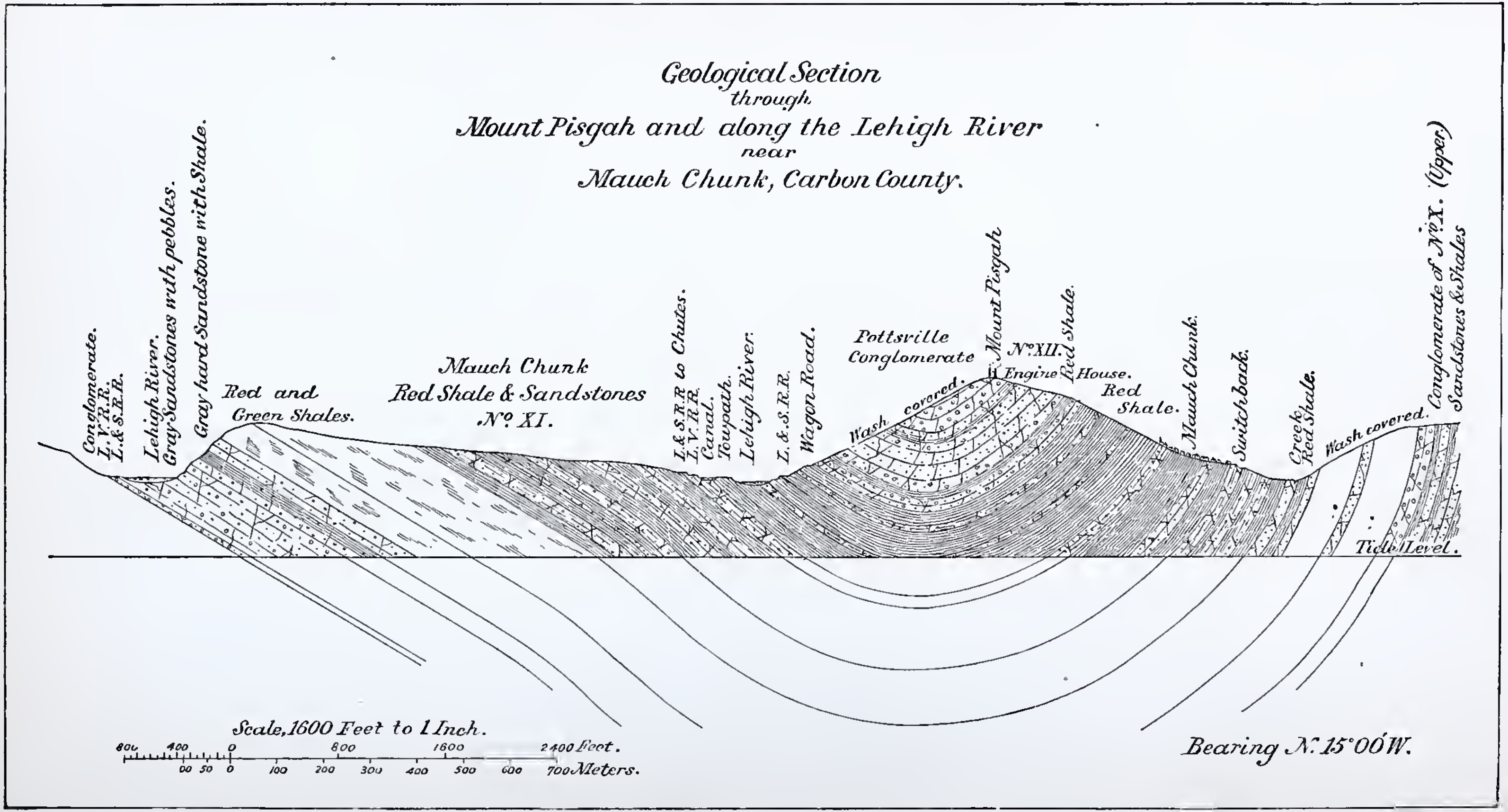
*The true classical method of naming flexures existing in sedimentary rocks, is to apply the name anticlinal to those strata which dip in opposite directions from a common ridge or axis like the roof of a house; and to apply the word synclinal to those strata which dip from opposite directions inward, like the leaves of an open book. In the case of the maps and reports to be published by the Anthracite Survey, I have diverged from this general plan, and will designate the latter by the word basin, rather than synclinal. This has been done for the reason that the word basin is more generally applied to the latter flexure by practical men, and has been universally assigned, with local names prefixed, to well recognized synclinals.

3. Locust Mountain Basin.

This basin forms the main trough of the strata under Mt. Pisgah. The axis of the basin crosses the Lehigh River in the Mauch Chunk red shale, No. XI, at a point 1800′ above the East Mauch Chunk bridge. The accompanying cross section* through Mt. Pisgah, at the head of the plane, shows the general shape of the basin at this point. The crest of the mountain is not directly over the axis of the basin. The latter at the engine house is about 450′ north of the former. As Hacklebarney tunnel is approached to the west, this basin gradually sinks, and the coal measures become folded and form two basins; as may be observed in section No. 1 (Cross section sheet No. I) through the old tunnel at Hacklebarney. At this point the tunnel cuts the Buck Mountain bed on both sides of the basin. At Mt. Pisgah there is but one basin in the Conglomerate, that of Locust Mountain. After the basin is broken into two subordinate synclinals, the northern one, or the Locust Mountain basin, gradually rises, and disappears entirely west of the tunnel, while the southern, or Hell Kitchen basin, broadens and dips to the west. The Locust Mountain basin never becomes deep enough to take in the Mammoth bed. Gen. Wm. Lilly, of Mauch Chunk, has directed my attention to the occurrence of this basin east of the Hacklebarney tunnel, where he claims the Buck Mountain bed has been opened along its outcrop. A personal examination has been made at this point, but the facts obtained were not such as to permit of the outcrop of the Buck Mountain bed being placed on the map. It is expected that a further survey will be made prior to the publication of the final report when more detailed facts will be given as to the special characteristics of this basin. East of the Lehigh River this basin is the synclinal of the area known as the Kettle, which is enclosed by the escarpment of Pocono rocks forming Kettle Mountain.

The base of the Pottsville Conglomerate, No. XII, in the center of the basin, north of Mt. Pisgah, is estimated to be at an elevation of 320′ above tide, at the Lehigh section,*

*Constructed by Ass't Arthur Winslow. All the drawings electrotyped for page illustrations were executed by Ass't O. B. Harden.


Geological Section
through
Mount Pisgah and along the Lehigh River
near
Mauch Chunk, Carbon County.
Conglomerate.
L.V.R.R.
L.& S.R.R.
Lehigh River.
Gray Sandstones with pebbles.
Gray hard Sandstone with Shale.
Red and Green Shales.
Mauch Chunk
Red Shale & Sandstones
No. XI.
L.& S.R.R to Chutes.
L.V.R.R.
Canal.
Towpath.
Lehigh River.
L.&.S.R.R.
Wagon Road.
Pottsville Conglomerate
Wash covered.
Mount Pisgah
No. XII.
Engine House.
Red Shale.
Red Shale.
Mauch Chunk.
Switchback.
Creek
Red Shale.
Wash covered.
Conglomerate of No. X. (Upper)
Sandstones & Shales
Tide Level.
Scale, 1600 Feet to 1 Inch.
800 400 0 800 1600 2400 Feet.
00 50 0 100 200 300 400 500 600 700 Meters.
Bearing N. 15° 00' W.

which cuts across the Kettle about one mile east of the river; the conglomerate is entirely eroded in the basin; the restored position of its lower horizon would be about 2600′ above tide. The distance of these two sections apart is 9,000′, and the course of the axis of the Locust Mountain basin between them is S. 70° W. The dip of the bottom of the basin to the S. W. is at the average rate of 14°.

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*4. Hell Kitchen Anticlinal.**

This anticlinal in all probability makes its first appearance in the strata about ¾ of a mile west of Mt. Pisgah engine house. It is cut by the Hacklebarney tunnel, where the Buck Mountain bed is passed through on both the north and south dips. Like the Locust Mountain basin, it disappears west of the tunnel. It is not possible, however, to trace it on the surface as it seems to make no mark upon the topography.

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5. Hell Kitchen basin.

The most eastern outcrop of the Mammoth bed in the Southern Coal Field is contained in this basin, at a point about ¼ of a mile east of Hacklebarney tunnel. Between this tunnel and No. 1, or Rhume Run tunnel, the strata on the southern side of the basin become overturned, and form the northern side of the Rhume Run overturned anticlinal. The deepest part of the basin is probably under Rhume Run tunnel. West of the tunnel it gradually rises, and the strata on either side are squeezed more closely together; the basin will probably be found to disappear entirely about half a mile west of slope No. 3.

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* The name Hell Kitchen in the Panther creek report must not be confounded with the name of the Green or Hell Kitchen Mountain (Upper Lehigh) basin, which is west of White Haven and south of Nescopec creek. The Hell Kitchen anticlinal and basin in the Panther creek region have been named from the Hell Kitchen run, which rises west of Hacklebarney tunnel, flows west in the center of the valley and falls into Nesquehoning creek, immediately north of the villiage of Nesquehoning.

6. *Rhume Run Overturned Anticlinal.*

This anticlinal probably affects the Mammoth bed first about midway between the Hacklebarney and Rhume Run tunnels. Like the Hell Kitchen basin, it disappears apparently somewhere in the territory between section lines Nos. 4 and 5. It separates the Greenwood basin proper from the Hell Kitchen basin. It has generally been supposed that what I have designated as the Hell Kitchen anticlinal, cut in the Hacklebarney tunnel, and the Rhume Run overturned anticlinal, cut in the Rhume Run tunnel, are the same, and that the Hell Kitchen basin, as developed in the former, is the same as the Greenwood basin, developed in the latter tunnel. They are evidently, however, independent flexures.

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7. *Greenwood Basin.*

The eastern extremity of this basin must be looked for at the point where the Rhume Run overturned anticlinal commences. It is boldly developed at the Rhume Run tunnel, and at this point forms the basin in which the most extensive mining operations have been carried on, with the exception of the northern side of the Hell Kitchen basin, where the Mammoth bed has been mined in gangways at fonr different levels. A noticeable feature, in the form of the basin here, is the sharpness of the bottom, which is clearly defined by the rock slope, which was driven up in the bottom of the basin, from what has been designated Phillips tunnel, west of Rhume Run tunnel (See section No. 2.) This basin is clearly defined in the Nesquehoning mines, and forms the basin at the mouth of Tunnel No. 6, through the south-dipping strata of which the tunnel passes. It is the only basin cut by the Nesquehoning railroad tunnel and Tunnel No. 8. In the latter, (See section No. 8,) the G, or Upper Red Ash, bed is cut by the tunnel, near the bottom of the basin. The strata in the bottom of the basin at this point, are squeezed into an anticlinal tongue forming two subordinate basins. The same feature may be seen in section No. 9, where the bed has been shafted on in the

Greenwood basin. In Tunnel No. 10 the same bed has been cut by the tunnel and two slopes driven down, one on either side of the anticlinal. In Greenwood slope, No. 2 tunnel, which is directly east of line of section No. 11, a number of crumplings in the Mammoth coal bed have been cut in this basin. The last indication of the Greenwood basin, and of the shaft anticlinal, which separates it from the Lansford basin, is found in the vicinity of Greenwood tunnel. In measuring the section of the strata exposed in Locust Mountain gap, it was supposed that some indication would be found of these two flexures. Although there is a continuous southern dip of the rocks in the gap, it was thought that the strata might be overturned, and in this way account for the excessive thickness (1700′) of the rocks between the E bed and the top of the Mauch Chunk Red Shale, No. XI. It was, however, decided that the strata were not overturned, after a careful examination of both sides of the gap, and of the topography between the gap and Greenwood tunnel.

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8. Shaft Anticlinal.

One of the most prominent structural features of the Panther Creek basin is this anticlinal, which is cut by Tunnel No. 2, directly south of shaft No. 1. Its name has been given from its close proximity to the shaft. This flexure forms an arch in the Mammoth bed about three fourths of a mile east of Rhume Run tunnel. Directly over the tunnel the Mammoth bed crops on the anticlinal. South of shaft No. 1 there is an area 900′ long and 100′ wide, more or less, where the bed has been eroded. This area is indicated by a dotted line on Mine sheet No. II. The anticlinal in the Mammoth bed is clearly defined by the Nesquehoning workings, from which to Tunnel No. 6 it has a course of about S. 70° W. Its axis crosses section No. 6 about 600′ in front of Tunnel No. 6. It is cut by Tunnel No. 7, near its mouth, and by Tunnel No. 8. Directly in front of the mouth of Tunnel No. 7, a wrinkle in the G bed occurs in the south dip, and forms a small flexure which has been mistaken for the Shaft anticlinal. In Tunnel No. 8 there is a falling of the strata in the middle of the anticlinal by which a little basin is formed, which is observed in the rocks underneath the G bed.

The anticlinal is cut in Tunnel No. 10, and the coal on what would be the north dip of the F or Lower Red Ash, if the strata were not overturned, is entirely squeezed out, as shown on cross section No. 10. As has been stated, the last indications of the anticlinal on the west are found in Greenwood slope, No. 2 tunnel.

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9. Lansford Basin.

The longest, broadest and the deepest basin under the Panther Creek valley is that which has been named the Lansford basin. The extreme eastern end of the Buck Mountain coal bed in this basin is 2850′ west of Hacklebarney tunnel at trial shaft No. 9. The outcrop of this coal bed around the end of the basin has been definitely located by trial shafts, whose positions are given upon mine sheet No. 1.

The basin, from a point about ¾ of a mile east of Nesquehoning tunnel west to a point in the vicinity of section line No. 5, is divided into two subordinate basins, which for convenience of reference, will be called the Northern or Lansford basin No. 2, and the Southern or Lansford basin No. 1, with a saddle between called the Mammoth anticlinal; so named, from the fact that the Mammoth bed, where it passes over the top of the anticlinal, has been cut by the Rhume Run tunnel. Basin No. 2 dies out to the east, before the outcrop of the Buck Mountain bed is reached. The outcrop of the bed, around basin No. 1, unites directly with the outcrop of the bed on the north dip of the Greenwood basin, passing around the Shaft anticlinal at a point 4800′ east of Nesquehoning tunnel. Both of these basins are clearly defined in the section through Rhume Run tunnel and Tunnel No. 2 (See Cross sections Nos. 2 and 3.) In the latter tunnel, the Mammoth anticlinal between the two basins is overturned towards the south.*

The G bed was located on the south side of the saddle, but is squeezed out on the north side, no representative of it being found there. The squeezing out of the bed here probably has a direct connection with the squeezing out of the Mammoth bed at the foot of slope No. 4, and the bulge in the coal bed in shaft No. 1 tunnel. The last direct evidence which we have of the existence of the Mammoth anticlinal towards the west is in Tunnel No. 2. It is probable, however, that it will be found to influence the shape of the Lansford basin, as far west as the point indicated. It is thought that the northern or more prominent of the two basins in the vicinity of Tunnel No. 1 is the one that dies out to the west. The general basin rises and becomes narrower to the west, attaining its greatest height three fourths of a mile east of Tunnel No. 5, and its minimum width between Tunnels Nos. 5 and 6. This feature of the structure is probably occasioned by the force which produced the Summit Hill anticlinal. This same force may occasion the squeezing together and narrowing of all the Panther Creek basins, to the north of Summit Hill. West of this point, the Lansford basin broadens and deepens, forming the first basin in front of Tunnels Nos. 7, 8, and 10, and Greenwood tunnel. West of the latter, it is the most northern basin of the Panther Creek valley, the rocks forming the Locust Mountain, north of Tamaqua, being the south-dipping rocks of the Lansford basin.

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10. Coaldale Anticlinal.

The most eastern indications which have been found in

* Most of the overturned or folded flexures met with in Pennsylvania are overturned toward the north, that is, what would otherwise be the northern dip of the anticlinal is inverted into a southern dip. Notable instanees of this kind of strueture are found in the Great Limestone No. II, of the Kittatinny valley. Well-known examples in the anthracite region are those of Rhume Run, Shenandoah, and Stanton overturns the latter in the vieinity of Wilkes Barre. The folding of the antielinal of Tunnel No. 2 to the South is an exeeption to the general rule, as mcst of these antielinals, as has been said, are folded to the north.

the mines, of the existence of this anticlinal, are in the extreme eastern workings from Panther Creek slope No. 4 and Tunnel No. 5. The anticlinal at this point is clearly illustrated by cross section No 5. Going toward the west from this point, the north dip of the anticlinal steepens very much. In the vicinity of Tunnel No. 5 it is nearly vertical. From this point towards the west a reversal takes place in the intensity of the dips on either side of the anticlinal, those on the north side becoming flatter, those on the south side becoming steeper, and probably overturned slightly in the vicinity of Tunnel No. 9. Where the line of this anticlinal crosses Tunnel No. 9, there were no strata found in place in the tunnel. All the rocks were broken up and confused, and on the original section of the tunnel which was constructed, a mud hole was shown at this point. From the tunnel the anticlinal takes a straight course through Coaldale to a point in front of breaker No. 10, where it bends to the south, passing under East Tamaqua in the vicinity of Union St. The crest of the anticlinal from its eastern extremity to Tunnel No. 5 falls rapidly to the west. From Tunnel No. 5 to Lansford it rises, and from Lansford it falls continuously to Tamaqua. No examination has as yet been made by the Survey west of Tamaqua, but it is probable that between Tamaqua and Tuscarora the Coaldale anticlinal disappears, and will be found to be replaced by the Dry Hollow (Summit Hill) anticlinal.

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11. Bull Run Basin.

This basin, which has been named from the fact that its axis passes directly to the south of the settlement of Bull Run, commences along the Sharp Mountain, south of the western extremity of the Nesquehoning mines. It is clearly defined by the Mammoth bed mine workings from Panther Creek slope No. 4, and Tunnel No. 5. It sinks rapidly to the west from this point, and passes under the northern end of Tunnel No. 5 in a nearly direct course to the foot of the old Summit Hill plane No. 1, over which the coal was originally hauled from the Panther Creek valley to the end of the Switch Back railroad, at Summit Hill. From this point the axis of the basin deflects to the south, and the basin probably attains its greatest depth between Coaldale and Bull Run, from whence its axis is nearly straight to Tamaqua. From Bull Run to Tamaqua it is probable that the basin rises. The Bull Run basin widens out rapidly south of Coaldale, and a local anticlinal and basin come in on its western slope. These flexures have been named Foster tunnel anticlinal and basin respectively, from the fact that they are clearly defined in the rocks cut by Tunnel No. 2, Foster's tunnel, (See section No. 9.)

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12. *Summit Hill Anticlinal.*

The Summit Hill anticlinal is one of the boldest and earliest recognized flexures in the anthracite region. It has special characteristics which are of interest to the student of structural geology, and has probably influenced the general shape of the Panther Creek basins more than any other flexure. Special reference to its structural features will be made in the final report. The anticlinal commences in a broad conglomerate area north-east of the Switch Back plane down Mt. Jefferson. It passes directly under Summit Hill village toward the west as a broad flat arch, which has made it possible to quarry the Mammoth bed from surface openings west of Summit Hill. South of the extremities of Tunnels Nos. 3 and 9 the flexure suddenly becomes sharper and narrower, and the roll dies away between the Summit Hill mines and No. 6 slope in Dry Hollow. What has generally been considered to be the Summit Hill anticlinal, west of this point, is in reality, the Dry Hollow anticlinal, which commences near Sharp Mountain, south of the old Summit Hill mine, worked from No. 1 slope. This fact is shown by the shape given to the Mammoth contours east of the Dry Hollow slope.*

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*On account of the close relationship existing between the Summit Hill and Dry Hollow anticlinals, it has been thought well, in designating them, to employ both names, preference being given to the latter.

13. Summit Hill Basin.

This basin is quite different in its structure from any of the Panther Creek basins, from the fact that it is practically a closed synclinal commencing south of Summit Hill, and ending east of the Dry Hollow slope. The general form of the basin is shown by cross sections Nos. 7 and 8, which pass directly through the mines worked from old slopes Nos. 1 and 2. The northern dip of the basin is very much steeper than the southern dip.*

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14. Dry Hollow Anticlinal.

This flexure commences along the Sharp Mountain about a mile south-west of Summit Hill. It passes in a nearly due west course to the head of No. 6 slope in Dry Hollow, at which point it deflects to the south, and passes immediately south of breaker No. 11, under the old Greenwood breaker, and passes under Tamaqua near the intersection of Patterson and Biddle streets. The exact position of this anticlinal, and its structural features, are shown on the cross section and mine sheets, having been determined in a general way from such surface facts as could be obtained, and a comparative study of the cross sections.

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15. Dry Hollow, Tamaqua and Sharp Mountain Basins.

The Dry Hollow basin lies between the anticlinal of the same name and Sharp Mountain, and has been considered to extend as far west as Tunnel No. 11, where the basin appears to be divided into two subordinate basins, named Tamaqua and Sharp Mountain respectively, separated by an anticlinal which has been designated as the Tamaqua

*In a report on the Panther Creek basins by Mr. R. P. Rothwell, he notes the following: "The northern dip of the basin is inverted in places, and the coal, having slipped upon itself, forms a peculiar doubling of the *vein.*" It was impossible to get into the mine at this point, or to get any facts to illustrate this feature, other than those which have been so clearly reported by Mr. Rothwell.

anticlinal. West from the tunnel the basins broaden and deepen, and the anticlinal between them broadens and rises. It is probable that west of the Little Schuylkill river these flexures will form a prominent part of the geological structure. Near Sharp Mountain there is every indication of the existence of a basin south of the Sharp Mountain basin. This has been named the Shaft basin, from the fact that it has been developed by a shaft in the mine workings on the western side of the river. A special study of this basin will be made when the surveys in the Pottsville basin, west of Tamaqua, are commenced.

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16. Deepening of the Panther Creek Basins Toward the West.

The general deepening of the Panther Creek basins to the west is shown on the longitudinal section on cross section sheet No. II. On this section the deepest point at which it is surmised the Mammoth bed occurs along the line of each section is given, as follows:

	Lowest Tidal Level of Mammoth Bed Basins.
Section No. 1,	+1140′
" " 2,	+ 200′
" " 3,	+ 250′
" " 4,	+ 100′
" " 5,	— 230′
" " 6,	— 330′
" " 7,	— 560′
" " 8,	— 740′
" " 9,	— 710′
" " 10,	— 650′
" " 11,	— 680′
" " 12,	— 970′

As may be observed from this section and table, there is a progressive fall in the general basin from the eastern outcrop of the Mammoth bed to a point opposite Tunnel No. 8, where the lowest point is 740′ below tide. From this point, to a point opposite Tunnel No. 10, there would appear to be a slight rise in the general basin; although, it is so nearly horizontal as mapped, that it is quite an open question whether there is a fall or rise at this point. From Tunnel No. 10 westward, the basins fall. The maximum longitudinal dip of the basins is between Sections Nos. 1 and 2, and Nos. 4 and 5. The dip of the individual basins in an eastern and western* direction may be obtained by measurement directly from the sections, or from the Mammoth contours. In the descriptions of the individual cross sections the elevation of the bottoms of the Mammoth basins and the tops of the Mammoth anticlinals are given where each section plane intersects the flexures. It must be remembered that many of these elevations which have been noted are purely hypothetical, being based upon a comparative study of the few facts which could be obtained in the unworked and unexplored areas. They are only proposed as the best conclusions which can be deduced from the facts at present available, and must necessarily be held open to revision, as additional information shall be obtained, through prospect workings or extension of the mines. The practical man must exercise caution and discrimination in the use of the estimates which have been made. No difficulty should be experienced, however, as actual facts are clearly distinguished from the hypothetical deductions on the Cross section and Mine sheets.

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17. Tidal Elevations Panther Creek Mine Sheets.

Old Hacklebarney Mine† (*abandoned*).

Mine Sheet No. I.

Mouth of tunnel,	1252.44
Apex of slope,	1273.73
Second level,	1140.50
Foot of slope, top of rail,	937.33
Gangway heading, third level, top of rail,	953.56

Nesquehoning Mines.

Tunnel No. 1, (Colliery abandoned.)

Mine Sheet No. I.

Top of rail, mouth of tunnel,	979.69

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* Eastern and western are used in a general sense; the general course of the Panther Creek valley and basins is about S. 16° W.

† Sometimes called Mauch Chunk tunnel.

Tunnel No. 2.

Mine Sheet No. II.

Top of rail, mouth of tunnel,	1049.23
Elevation of surface in first ravine west of tunnel on outcrop of Red Ash bed, (proposed location of slope,)	1230.11

Slope No. 1, (abandoned.)

Mine Sheet No. I.

Apex of slope,	1041.88
Tunnel No. 1 level, (water level,)*	979.69
Second level of slope,	816.09
Third level,	633.73
Fourth level, (bottom,)	468.59

Slope No. 2, (abandoned.)

Mine Sheet No. II.

Apex of slope,	1055.63
First level below tunnel No. 1, or bottom of slope,	865.63

Slope No. 3.

Mine Sheet No. II.

Cross casting, foot of outside plane,	1070.31
Apex of same,	1149.72
Apex of slope,	1151.02
First level or tunnel No. 1 level,	1011.06
Second level or bottom of slope,	878.26

Slope No. 4, (abandoned.)

Mine Sheet No. II.

Apex of slope,	1100.11
Level of gangway from tunnel No. 2,	1054.33
Bottom of slope,	948.61

Shaft No. 1.

Mine Sheet No. II.

Top of shaft No. 1,	1074.86
Foot of same,	764.86

Drift in G. bed.

Mine Sheet No. II.

Mouth of drift,	1070.47

Summit Hill Mines.

Tunnel No. 1, (Spring Tunnel.)

Mine Sheet No. III.

Mouth of tunnel,	1266.4
Level of slope No. 2, (1st lift,)	1271.15

* In designating the different parts of a mine the conventional names of the local engineers are generally used. The word gangway is seldom used in this district in connection with the word level, although it is understood.

Slope No. 2, (abandoned.)

Mine Sheet No. III.

Top of rail, level surface of ground slope No. 2,	1371.99
Second level on slope,	1197.21
Third level on slope or waterway,	1113.01
Mouth of waterway,	1100.46
Fourth level on slope,	1033.61
Fifth level on slope,	960.98
Point in leg, foot of air hole from 5th level gangway west,	974.33
Iron point, head of air hole to 6th level gangway west,	968.60
Sixth level on slope,	870.15
Iron point in leg on east side, foot of slope,	871.57
Top of rail near heading, east side 6th level,	881.86
Top of rail, 12th breast from foot of slope, west side,	872.73
Iron point, foot of air hole to 5th level,	884.79
Top of rail at heading of west gangway 6th level,	883.21
Iron point in leg, east side of slope between 5th and 4th level marked F,	1007.66
Iron point, tunnel, No. 9 at head of air hole from slope No. 2, 5th level,	1009.64

Panther Creek Mines.

Tunnel No. 2.

Mine Sheet No. II.

Top of rail, mouth of tunnel,	978.70
Iron point, heading of tunnel,	985.10
Surface directly over air hole in fault, east gangway,	1268.22
Heading of air hole in rock fault,	1197.18
Gangway level, foot of air hole,	992.70
Outcrop of Red Ash, south dip, on tunnel line,	1276.56
Outcrop of Red Ash, north dip, on tunnel line,	1348.00
Outcrop of 30′ bed,	1381.81
Outcrop of 18′ bed,	1395.00

Tunnel No. 3.

Mine Sheet No. III.

Mouth of tunnel,	1209.58

Tunnel No. 4.

Mine Sheet No. II.

Mouth of tunnel,	1190.72

Tunnel No. 5.

Mine Sheet No. II.

Top of rail, mouth of tunnel,	1142.58
Top of rail, head of tunnel,	1148.59
Old landing, slope No. 4,	1301.92
Foot of 2d level,	897.46
Third level, foot of slope No. 4,	650.06

Tunnel No. 6.

Mine Sheet No. II.

Top of rail, mouth of tunnel,	1072.47
Top of rail, apex of slope No. 3,	1076.39
Top of rail, foot of slope No. 3,	869.42
Heading, west gangway,	897.66
Heading, east gangway,	903.15
Top of rail in tunnel, west outcrop,	1238.65
Apex of letting down plane,	1232.84
Apex of east slope,	1373.75
Bottom of east slope, gangway level,	1070.04
Bottom of west slope, gangway level,	1102.46
Top of rail, 1st turnout west,	885.06
Top of rail, main road, under breaker,	1067.14
Surface on mountain over fire, in tunnel No. 6,	1377.97

*Tunnel No. 7.**

Mine Sheet No. II.

Top of rail. north end of tunnel,	1012.89
Top of rail, south end of tunel,	1015.00
Iron point, south end of tunnel, west side,	1015.46
Iron point in east side of arch, through Mammoth bed,	1018.67
Iron point, south-west corner of Lansford office,	1017.71

Tunnel No. 8.

Mine Sheet No. III.

Top of rail, mouth of tunnel,	962.32
Head of tunnel,	969.32
Second level,	756.28
Third level,	587.59
Outcrop of Mammoth bed, tunnel line,	1267.23
Apex small slope on mountain,	1283.19
Foot of small slope on mountain,	1181.35
Mouth of tunnel, near outcrop,	1181.62
Landing at tunnel, slope No. 5,	970.30

Tunnel No. 9.

Mine Sheet No. II.

Top of rail, 1st Red Ash bed,	988.09
End of tunnel,	993.66
Top of rail at 7th breast in east tunnel level gangway, east of plane No. 1,	1007.98
Apex of letting down plane, east gangway,	1082.00
Apex of slope, tunnel level,	995.57
Foot of slope, 2d level,	851.45
Gangway of old No. 4 tunnel, at air hole to plane No. 12,	1209.69
Where counter gangway connects with air hole,	1292.82
Surface of 1st air hole, east of old No. 1 plane,	1393.06

*All mining has been abandoned from this tunnel. It now forms the south end of the Nesquehoning Valley railroad (Tamaqua Branch) tunnel between Lansford and Hauto.

Mine Sheet No. III.

Top of rail, mouth of tunnel,	984.13
Top of rail under new breaker, Tamaqua Branch R. R.,	981.21

Tunnel No. 10.

Mine Sheet No. III.

Top of rail, mouth of tunnel,	958.34
Top of rail under No. 10 breaker,	892.04

Tunnel No. 11.

Mine Sheet No. III.

Top of rail, mouth of tunnel,	1043.87

Slope No. 6 (Dry Hollow Slope).

Mine Sheet No. III.

Apex of slope,	1298.04
Foot of slope,	1115.04

Slope No. 7.

Mine Sheet No. II.

Top of pumpway,	1163.24
Apex of slope,	1464.30

Greenwood Mines (Closed).

Tunnel No. 1 (Greenwood Tunnel).

Mine Sheet No. III.

Mouth of tunnel,	913.91

Slope No. 1. F Bed.

Mine Sheet No. III.

R. R. spike in cribbing, at apex,	1097.47
Top rail, surface landing,	1094.23
First or tunnel level,	918.80
Second level,	656.96
Top of rail, 3d level, (foot of slope,)	435.95 *

Slope No. 2. E Bed. (Greenwood Slope.)

Mine Sheet No. III.

Top of rail, lower landing,	1165.20
First level,	944.88
Level of gangway from tunnel No. 10,	811.83
Second level, (foot of slope.)	734.02
Top of rail, north end of inside tunnel to Mammoth bed,	746.02

* This is the only locality in the Panther Creek basin where any coal has been mined below an elevation of 500′ above tide level.

Slope No. 4. E Bed.

Mine Sheet No. III.

Bolt head in stringer, west side of slope,	1077.89
Approximate elevation of foot,	644.00
Approximate elevation of drift level on D bed,	878.73
Approximate elevation of drift level on E bed,	852.81
Apex, Swartz slope,	1159.35
Gangway level, foot of Swartz slope,	1075.52

Levan's Slope. F Bed, (abandoned.)

Mine Sheet No. III.

Apex of slope,	888.40
Gangway level, foot of slope,	630.97

Tamaqua Mines.

Slope on Sharp Mountain. E Bed, (abandoned.)

Mine Sheet No. III.

Apex of slope,	832.31
Where water runs from old drift,	785.31
Foot of slope,	639.07
Heading of inside gangway,	671.78
Heading of drift,	1142.58
Top rail, mouth of Randall's drift,	826.21

Miscellaneous Elevations.

Mine Sheet No. I.

Junction of the Lehigh and Susquehanna and Nesquehoning Valley Railroads,	532.30
Nesquehoning depot,	801.10

Mine Sheet No. II.

Head of Mt. Jefferson Plane,*	1539.7
Foot of Mt. Jefferson Plane,	1042.4
Summit Hill depot,	1498.36
Lansford office, Lehigh Coal and Navigation Co., southwest corner, (B. M. iron point,)	1017.71

Mine Sheet No. III.

Top of old No. 2 plane, (abandoned,)	1206.7
Tamaqua depot, Tamaqua Branch, L. & S. R. R.,	801.8
Broad street, Tamaqua, at crossing of Philadelphia and Reading R. R.,	797.78

The description of the points of elevations, given in the the original notes, is preserved as far as possible in the above tables.

*The elevations given in Report N, page 70, of the Switch Back R. R., are to be questioned. They differ from several elevations found among the level notes of the L. C. & Nav. Co.

CHAPTER III.

1. Panther Creek Cross Section Sheets; 2. Section No. 1 through Old Tunnel at Hacklebarney; 3. Section No. 2 from Nesquehoning Valley to Mauch Chunk Valley through Rhume Run (No. 1) Tunnel; 4. Section No. 3 through Tunnel No. 2; 5. Section No. 4, 330 feet west of Slope No. 3 Nesquehoning; 6. Section No. 5 through east end of workings of Tunnels Nos. 5 and 6 and Slope No. 4 and west end of Nesquehoning workings; 7. Section No. 6 through Tunnels Nos. 5 and 6 and Slope No. 4 workings; 8. Section No. 7 through Tunnels Nos. 4 and 7 and Slope No. 1 workings; 9. Section No. 8 through Tunnels Nos. 8 and 9 and Slope No. 2 workings; 10. Section No. 9 through Herring's Hollow, Tunnel No. 2 (Foster's Tunnel) and Dry Hollow Slope; 11. Section No. 10 through Tunnels Nos. 10 and 11; 12. Section No. 11 through Tunnel of Greenwood Slope No. 2 and Tunnel No. 11 workings; 13. Section No. 12 along the Little Schuylkill River showing the structure of the Pottsville Conglomerate No. XII in the Locust and Sharp Mountain gaps at Tamaqua.

1. Panther Creek Cross Section Sheets.

In constructing these sections the method pursued was as follows: The general structure of the entire basin as represented by the mine maps (scale 100′=1″) and vertical cross sections (scale 200′=1″), in the possession of the Lehigh Coal and Navigation Company, were carefully examined and the points, where the structure was considered most difficult and least known, were determined; from this examination locations were established where it was considered desirable for the Survey to construct a section for publication. Sections were first made independently from the facts, on record in the company's office, in the immediate vicinity of the line of the section. In many instances these facts had already been incorporated into cross sections constructed by the company's engineers; and, where a subsequent examination by the Survey verified these sections or parts of them they have been directly reproduced on the accompanying sheets. No one of the twelve sections, however, agrees throughout with those which had previously been constructed: field examinations for the sections, made by the Survey in every case introduced important modifications. In those parts where there were but few facts obtained the anticlinals and synclinals were drawn in hypothetically.

After each section was constructed in this way, they were all studied collectively and each one was materially modified, by a comparison of its structure with that shown in the adjoining sections. In this way a second construction was obtained, which without doubt more nearly approached the actual position of the strata. Field examinations were next made in the vicinity of each section; both on the surface and inside of the mines, wherever the structure was particularly difficult or uncertain and where it was thought additional facts could be collected. Thus a second change was made in most of the sections and a third solution of the geological structure procured.

The floor of the Mammoth coal-bed was then contoured (curves 50 feet vertically apart) from the mine maps and the cross-sections thus constructed; it was discovered, however, that in many minor particulars the structure shown by the sections had to be changed; since it was thought, that the direction and fall or rise, which the cross sections indicated for the anticlinals and basins, were abnormal. By this method, a final solution of the geology was obtained, as illustrated by the cross sections on the atlas sheets. The structure under the areas where the coal beds have not been actually located, either by mining or prospect bore-holes or shafts, is probably as correctly represented as it is possible to do without practical explorations.

All theoretical deductions, especially in structural geology, must be accepted as such. The anthracite coal beds are subject to such unexpected and oftentimes inconceivable *freaks*, in the numerous foldings which they make, that it is frequently impossible to even suggest a solution of the structure. Such theoretical deductions must, however, necessarily precede a practical exploitation of the coal beds; their explanation of the geological structure, as the mining will ultimately disclose it, is directly proportional to the number of observed facts and the experience and judgment of the investigator. In printing these sections an effort has been made to clearly separate all facts from hypotheses; so that, as future facts shall be obtained they may be added to those already recorded in the sections, and confirm, modify or disprove the hypothetical structure, which is offered as a provisional, rather than as a final solution.

The plan of representation has been as follows: Wherever the character of the strata is known they have been shaded; all coal beds whose positions have been certainly determined are printed in full black; when the plane of section passes through a gangway or breast from which the coal has been taken a white space has been left, with the top and bottom of the bed indicated by a single line in each case; where the position of the bed has been determined hypothetically, the bottom of the bed has alone been marked by a single line.

The vertical planes upon which the sections have been projected are placed at right angles to the general direction of the axes of the basins or synclinals across which they pass. The direction of the Panther Creek basins changes very much between Mauch Chunk and Tamaqua, so that the sections are not parallel. Most of the strata shown have been located along the plane of section; in cases where they are located at some distance away, their position on the plane of section have been found by projections along the line of strike.

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2. Cross-Section No. 1.

Through Old Tunnel at Hacklebarney.

This section passes through Hacklebarney tunnel. The mouth of the tunnel is under the Switch Back gravity railroad, at a point 8,200′ west of the Mount Pisgah engine-house. It commences in the Pottsville conglomerate, No. XII, and crosses the basin to a point below the Buck Mountain bed, on the south dip. The direction of the section line is S. 22° E. All the coals in the eastern end of the basin are cut, amounting, in the aggregate, to 114′, divided into eleven distinct beds (Columnar section sheet I, section 4.*)

The following section has been measured of the strata from the Mammoth bed, in the Hell Kitchen basin, to the mouth of the tunnel.

Section No. 4. Columnar Section Sheet No. I.
Hacklebarney Tunnel.

	Rock.	*Coal beds.*		*Total.*
1. E (MAMMOTH) COAL BED,		50′	to	50′ †
2. Sandstone,	10′		to	60′
3. COAL BED,		4′	to	64′
4. Hard sandy slate,	34′		to	98′
5. COAL BED,		19′	to	117′
6. Slate,	9′		to	126′
7. COAL BED,		7′	to	133′
8. Slate,	4′		to	137′
9. Slate,	14′		to	151′
10. Dirt seam,		—		——
11. Sandy slate,	6′		to	157′
12. COAL BED,		2′	to	159′
13. Sandy slate,	35′		to	194′
14. Soft slate,	2′		to	196′
15. Sandy slate,	16′		to	212′
16. Sandstone,	14′		to	226′
17. Conglomerate,	10′		to	236′
18. Coal, dirt, and slate,	1′		to	237′

* The total thickness of coal beds on the section sheet should be 114′ instead of 112′.

† In the tables of mining estimates (See Chapter VI.) the average thickness of the coal beds where mined is given, together with the amount of coal which has been taken from each bed. Most of the bed thicknesses, given in the columnar sections, have been measured at special localities, and sometimes show more or less than the thickness which could be depended upon, as an average over any considerable area.

NOTE.—A number of the columnar sections in the Panther Creek Valley are published just as they were reported to the Survey. Many of them have been made by different observers and at different times; so that, the same names, used in describing the rock strata, do not always indicate an identical character.

19. Sandstone and conglomerate,	50'		to 287'
20. Dirt seam,	2'		to 289
21. Slate,	3'		to 292'
22. Sandstone,	9' 6"		to 301' 6"
23. Conglomerate,	15' 6"		to 317'
24. COAL BED,		3'	to 320'
25. Slate,	4'		to 324'
26. COAL BED, (COAL AND SLATE,)		2'	to 326'
27. Conglomerate,	4'		to 330'
28. COAL BED,		3'	to 333'
29. Conglomerate,	38'		to 371'
30. COAL BED,		7'	to 378'
31. Slate,	3'		to 381'
32. B (Buck Mountain) COAL BED,		9'	to 390'
33. Slate,	14'		to 404'
34. COAL BED,		8'	to 412'
35. Slate,	6' 6"		to 418' 6"
36. Conglomerate and sandstone,	31'		to 449' 6"
37. White conglomerate,	14' 5"		to 463' 11"
38. Coal, slate, and dirt,	2'		to 465 11"
Total thickness of rock,	351' 11"		
Total thickness of coal beds,		114'	

The following section is a continuation of the above. Stratum No. 38, Section No. 4, being equivalent to Stratum No. 1, Section No. 46.

Section No. 46, Columnar Section Sheet No. II.

Hacklebarney Tunnel.

	Rock.		*Total.*
1. COAL BED.			
2. Slate,	6' 6"	to	6' 6"
3. Conglomerate and sandstone,	31'	to	37' 6"
4. Large white nut conglomerate,	14' 5"	to	51' 11"
5. Coal slate and dirt,	2'	to	53' 11"
6. Small nut conglomerate,	36'	to	89' 11"
7. Conglomerate and sandstone,	20'	to	109' 11"
8. Nut conglomerate,	61' 8"	to	171' 7"
9. Nut conglomerate,	73' 6"	to	245' 1"
10. Conglomerate,	16' 6"	to	261' 7"
11. Nut conglomerate,	63' 6"	to	325' 1"
12. Conglomerate,	81'	to	406' 1"
13. Nut conglomerate,	23'	to	429' 1"
14. Egg conglomerate,	28'	to	457' 1"
15. Nut conglomerate,	41'	to	498' 1"
16. Nut conglomerate,	49'	to	547' 1"
17. COAL.			
18. Nut conglomerate,	1'	to	548' 1"
19. Nut conglomerate,	64'	to	612 1"
20. Sandstone,	5'	to	617' 1"

21. Conglomerate,	15′	to	632′	1″
22. Sandstone,	4′	to	636′	1″
23. Nut conglomerate,	38′	to	674′	1″
24. Egg conglomerate,	10′	to	684′	1″
25. Nut conglomerate,	22′	to	706′	1″
26. Concealed,	405′	to	1111′	1″

The nut conglomerate of stratum No. 25 is at the mouth of the tunnel; from this point to the top of the Mauch Chunk Red Shale No. XI, on the slope below the tunnel, there is a thickness of 305′ of measures. No division line has been established here or elsewhere in the Panther Creek basin between the *Productive Coal Measures* proper and the *Pottsville Conglomerate No. XII.* The actual distance, perpendicular to the bedding, from the bottom of the Mammoth bed to the top of the Mauch Chunk shale is (465′ 11″—50′)+1111′ 1″=1527′) 1527′. On account of the difficulty of locating the top of the Mauch Chunk exactly, and from the fact that the conglomerate strata near the mouth of the tunnel are considerably twisted, it is impossible to accept this as a precise measurement.*

The identification of the individual beds in this section with those developed to the west has never been satisfactorily determined; a comparison is suggested, however, upon both the columnar and cross section sheets.. A consideration of this subject, in detail, is deferred until the publication of the final report. The second bed, known as the Buck Mountain, encountered in the tunnel, and the bed in the center of the first basin crossed, (Hell Kitchen) known as the E or top split of the Mammoth bed, which is the highest geological stratum cut, have both been mined. The conglomerate strata near the mouth of the tunnel have been overturned from a north to a south dip. This is a common feature of all the strata along the Sharp Mountain, and may be beautifully observed in the Little Schuylkill gap south of Tamaqua, and in the Schuylkill gap at Pottsville. The structure of the rocks cut in the tunnel north of the Hell Kitchen or Mammoth basin has always been misleading, on account of the commencement of the overturning of the Hell

*The interval has been stated as 1550′ instead of 1527′, on Columnar section sheet II, section 51.

Kitchen anticlinal, which produces a general south dip to the strata. The Buck Mountain bed is cut on either side of the anticlinal on both the south and overturned north dips.

*Elevations of Coal Beds in Plane of Section No. 1.**

Mammoth Bed.

Outcrop Hell Kitchen basin,	**1360′** †
Bottom " " "	1140′

Buck Mountain Bed.

North outcrop Locust Mountain Basin,	1430′
Bottom " " "	*890′*
Top Hell Kitchen anticlinal,	1355′
Bottom Hell Kitchen basin,	*625′*
South outcrop Hell Kitchen basin,	1380′

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3. Cross Section No. 2.

From Nesquehoning Valley to Mauch Chunk Valley through Rhume Run No. 1 Tunnel.

The facts for the construction of section No. 2 are very extensive and complete, and were obtained in Rhume Run gap back of Nesquehoning, Rhume Run (No. 1) tunnel, and in the mines directly adjoining the tunnel. The facts incorporated into this section are not new, for this tunnel and mines are among the oldest in the anthracite coal fields. In 1840 Prof. Rogers' assistants on the First Geological Survey made a survey and examination of the tunnel and mines, and a section was constructed and published in the

* The elevations of special points in the coal beds, in the plane of each section, given after the description of the section, are those which have been used in the construction of the sections. In some instances, for the Mammoth bed, they will be found to differ a few feet from the elevations indicated by the contours in the floor of the bed, on the mine sheets. These slight differences were occasioned by alterations made on the proof sheets of the sections. The changes were not sufficient, however, to warrant the correction of the contours on the mine sheets, which at the time the changes were made were in the engravers' hands.

† All elevations which have been absolutely determined by instrumental observations are printed in a boldfaced type; those which have been approximately determined are printed in ordinary type; and those which have been estimated, in italics.

final report.* Since that time other surveys have been made from time to time, and numerous sections constructed, variously interpreting the structure, until the problem which they have sought to solve has become known as the "*Lehigh Riddle.*"

In 1869 Mr. R. P. Rothwell constructed a section which accompanies the annual report of the Lehigh Coal and Navigation Company for that year; the general structure of this section resembles very much that now published by the Geological Survey; it differs, however, in many important details, as for instance, the depth of the basin and the height of the anticlinals—of the latter, that which I have called the Mammoth anticlinal may be particularly noted. On the Rothwell section, the Mammoth bed saddles at this point about 150 feet below the tunnel level, whereas in the Survey section the Mammoth bed on this anticlinal is intersected by the tunnel. Since 1869 a section, which more nearly resembles the present one, has been constructed by Mr. W. D. Zehner, superintendent of the company. One of the greatest difficulties in the structure of the section was the general south dip of all the coal beds from the mouth of the tunnel to the center of the Greenwood basin. At first it was supposed that each one of these coals represented a separate bed; an overturning of some of the strata was afterwards suggested, which later was actually proved by mining. The identification of the beds, which is indicated in the section, seems now to be placed beyond a doubt, although previous sections make a different interpretation of the structure. A comparative study of these sections has been made and a detail description of the special points involved will be subsequently made in the final report. The direction of the plane of the section is S. 8° E. and is 10,900′ west of section No. I.† All the coal beds in this part of the basin are cut by this tunnel. The synclinal of the G bed just descends to the tunnel in the Greenwood basin.

* Vol. II, page 54.

† The planes of the Panther Creek sections are not parallel. The distances between the sections have been measured along the center of the Panther Creek Valley.

The Lykens Valley beds which were located in the Locust Mountain gap north of Tamaqua (Cross section sheet No III, sec. No. 12) were not found in the Rhume Run gap. There is a total thickness of coal beds in the tunnel of 56 feet, that is from the mouth to the F or Lower Red Ash bed. Most of the beds are encountered several times so that the actual thickness of coal cut by the tunnel is very much greater.

The following section has been measured of the strata from the center of the Hell Kitchen basin to the mouth of Tunnel No. 1.

Section No. 2.—Columnar Section Sheet No. I.—Tunnel No. 1.

	Rock.	*Coal beds.*	*Total.*
1. Slate,	5′ 8″		to 5′ 8″
2. Sandstone,	49′ 1″		to 54′ 9″
3. Slate,	5′ 10″		to 60′ 7″
4. Sandstone,	2′ 10″		to 63′ 5″
5. Slate,	9′ 2″		to 72′ 7″
6. Red Ash coal bed,		22′ 8″	to 95′ 3″
7. Slate,	21′ 4″		to 116′ 7″
8. Sandstone,	29′ 5″		to 146′
9. Slate,	24′ 7″		to 170′ 7″
10. Sandstone,	8′ 3″		to 178′ 10″
11. Slate,	12′ 1″		to 190′ 11″
12. Coal bed,		5′ 5″	to 196′ 4″
13. Slate,	7′ 3″		to 203′ 7″
14. Sandstone,	55′ 11″		to 259′ 6″
15. Mammoth coal bed,		13′ 10″	to 273′ 4″
16. Slate,	11′ 6″		to 284′ 10″
17. Sandstone,	54′		to 338′ 10″
18. Coal bed (coal and slate,)		11′	to 349′ 10″
19. Slate,	11′		to 360′ 10″
20. Conglomerate,	41′		to 401′ 10″
21. Slate,	10′		to 411′ 10″
22. Conglomerate,	57′ 6″		to 469′ 4″
23. Slate,	16′		to 485′ 4″
24. Coal bed,		3′	to 488′ 4″
25. Slate,	15′		to 503′ 4″
26. Sandstone,	45′		to 548′ 4″
Total thickness of rock,	492′ 5″		
Total thickness of coal beds,		55′ 11″	

A measurement of some of these same strata was made in another portion of the tunnel and is shown below.

Section No. 1.—Columnar Section Sheet No. I.—Tunnel No. 1.

	Rock.	Coal beds.	Total.
1. RED ASH COAL BED,		15′ 10″	to 15′ 10″
2. Slate,	111′ 11″		to 127′ 9″
3. COAL BED,		7′ 9″	to 135′ 6″
4. Conglomerates,	34′ 9″		to 170′ 3″
5. Slate,	4″		to 170′ 7″
6. Conglomerate,	4′ 10″		to 175′ 5″
7. COAL BED,		3′ 4″	to 178′ 9″
8. Slate,	25′ 8″		to 204′ 5″
9. MAMMOTH COAL BED,		23′ 11″	to 228′ 4″
Total thickness of rock,	177′ 6″		
Total thickness of coal beds,		50′ 10″	

The Carboniferous conglomerate is exposed in the Rhume Run gap north of Tunnel No. 1 and is represented by the following section. No upper limit has been assigned to the Pottsville conglomerate.

Section No. 47.—Columnar Section Sheet No. II.—Pottsville Conglomerate No. XII (+) Rhume Run Gap.

	Rock.	Total.
1. COAL BED,	—	to
2. Slate,	15′	to 15′
3. Sandstone,	70′	to 85′
4. Concealed, 5. 'A' COAL BED, (Rothwell,) 6. Concealed,	130′	to 215′
7. Small pebble conglomerate,	40′	to 255′
8. Massive conglomerate,	180′	to 435′
9. Partly concealed,	80′	to 515′
10. Conglomerate,	160′	to 675′
11. Conglomerate, (mostly concealed,)	130′	to 805′
12. Conglomerate,	30′	to 835′
13. Gray sandstone,	20′	to 855′
14. Conglomerate with pea pebbles,	20′	to 875′
15. Sandstone,	25′	to 900′
16. Conglomerate and sandstone,	35′	to 935′
17. Conglomerate,	35′	to 970′
18. Sandstone,	35′	to 1005′
19. Conglomerate and sandstone,	40′	to 1045′
20. Sandstone,	30′	to 1075′
21. Slate and sandstone,	40′	to 1115′
22. Sandstone,	30′	to 1145′
23. Conglomerate,	10′	to 1155′
Mauch Chunk Red shale, No. XI.		

Elevations of Coal Beds in Plane of Section No. 2.

Mammoth Bed.

North outcrop of Hell Kitchen basin,	1110′
Bottom of Hell Kitchen basin,	*200′*
Top of Rhume Run overturned anticlinal,	655′
Bottom of Greenwood basin,	*525′*
Top (outcrop) of Shaft anticlinal,	1260′
Bottom of Lansford basin, No. 2,	*715′*
Top of Mammoth anticlinal,	1030′
Bottom of Lansford basin, No. 1,	*490′*
South outcrop of Lansford basin, No. 2,	1370′

F or Lower Red Ash Bed.

North outcrop of Hell Kitchen basin,	1135′
Bottom of Hell Kitchen basin,	*545′*
South outcrop of Hell Kitchen basin,	1170′
North outcrop of Greenwood basin,	1175′
Bottom of Greenwood basin,	840′
South outcrop of Greenwood basin,	1225′
North outcrop of Lansford basin, No. 2,	1270′
Bottom of Lansford basin, No. 2,	*880′*
South outcrop of Lansford basin, No. 2,	1260′
North outcrop of Lansford basin, No. 1,	1265′
Bottom of Lansford basin, No. 1,	*790′*
South outcrop of Lansford basin, No. 1,	1310′

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4. Cross Section No. 3.

Through Tunnel No. 2.

This section passes through Tunnel No. 2 in a direction S. 16° 10′ E. and is 1550 feet west of Tunnel No. 1. The general features of the structure here are very similar to those of section No. 2. The rapid deepening of the basins which is observed between sections Nos. 1 and 2 does not seem to continue between Nos. 2 and 3, in fact there are evidences that there may be a slight rise in the basins toward the west, between these two latter sections. The principal difficulties which have been encountered in the geology here lie to the south of shaft No. 1. The tunnel cuts the Mammoth bed on both the north and south dip of the shaft anticlinal, which I have so named from the close proximity of shaft No. 1. The south dip was mined from slope No. 4*

* This is generally called Nesquehoning slope No. 4, in distinction to the slope above Tunnel No. 5 which is known as Panther Creek No. 4 slope.

which was driven in the lower part of the bed to a vertical depth below the apex of the slope of 151.5 feet.

At this depth the bed pinched out and was lost: a gangway was driven both east and west from the foot of the slope and much coal taken out from the south dip; no clue was discovered, however, as to how the bed had been cut off and where it went. Shaft No. 1 was then sunk to a depth of 310′ on the north dip of the bed and gangways driven east and west. From the west gangway, at a point about 350′ from the bottom of the shaft, a tunnel has been driven S. 14° 15′ (±) E. or nearly parallel to Tunnel No. 2. At a distance of 650′ from the shaft gangway, in this tunnel, a hard white ash bed was cut, in which a gangway was driven east and west. Before this bed was reached three small beds were passed through, one directly under the 'shaft' Mammoth and two further on, all of which are shown in section. It was supposed that the large bed encountered was the Mammoth and mining was planned, in order to obtain a connection. if possible, between this point and the bed worked in the bottom gangway of slope No. 4. Pròving holes were driven up along the top slate; but, instead of their leading up to the slope workings, they turned to the south, at about a height of 30 feet and afterwards descended to the level of the tunnel, following continuously the line of contact between coal and slate; the details of these workings are shown in the enlarged section (scale 20′ =1″) accompanying section No. 3. No break was observed in the strata, where there could be a possible connection with the Mammoth bed at the point at which it pinched out at the foot of slope No. 4. A small *irregularity* was discovered in the roof of the arch at one point, and it was thought that it might indicate a possible outlet to the upper workings; but, I am led to conclude, from a close examination of this slate roof, that the strata form a regular anticlinal arch over the coal. The crest of the anticlinal, if such it be, dips rapidly to the west, the angle being about 12° in the vicinity of the tunnel. In the gangway driven east, the bed pinched out at about 800′ from the tunnel and terminated in the same abrupt manner in the west gangway about 350′ from the tunnel. The top of the coal 800′ east of the tunnel was found to be 140′ above the tunnel level. The greatest horizontal north and south thickness of the coal was 125′ about 125′ east of the tunnel and the greatest height 30′.

The third small bed below the "shaft" Mammoth passed through in the tunnel, seems to be directly connected with this large body of pocketed coal; so that, if a connection ever existed between this coal and that at slope No. 4, it should be sought for from this small bed rather than from the larger body; but a careful study of the section would seem to relate this small bed with the first bed under the Mammoth, instead of with the Mammoth, so that we would be forced to the conclusion that the pocketed bed is an enlargement of the bed under the Mammoth. The character of the pocketed coal would, however, seem to militate against such a reasoning. A great deal of coal was mined from this point, and it is said to have resembled in every way the best hard white ash Mammoth ever shipped from the Company's property. This solution of the structure would seem to necessitate other conclusions which are hardly warranted by facts. For instance, coal bed F in Tunnel No. 2, on the south dip, would apparently be the same coal as bed G on the north dip near the face of the tunnel, whereas the character of this F bed and its immediately associated strata is the same as of the F bed, so-called, at the head of the tunnel. In order to ascertain if any light could be thrown on these structural difficulties by an examination of the constitution of the coal, Mr. McCreath made analyses of selected specimens of coal from the following localities: the bed underneath the Mammoth near the mouth of Tunnel No. 1; the Mammoth bed at shaft No. 1; the "pocketed bed;" and the south and north dipping F or Lower Red Ash bed in Tunnel No. 2. These analyses (See page 187) give no assistance in identifying the "pocketed coal" with either the Mammoth or the bed underneath, but do seem to indicate that the two red ash beds, one on the south and the other on the north dip, in Tunnel No. 2 are the same.

Greater variations are shown in the proportion of elements in two specimens of coal taken near together from the "pocketed bed" than in specimens taken from different beds. The tunnel from shaft No. 1 gangway has now (November, 1882,) been driven as far as the F bed, which it cut at a distance of 1090′ from the gangway; the G bed was passed through 89′ north of the top of the F bed. There seems to be no doubt left as to the proper naming of the red ash beds in Tunnel No. 2, as shown on the section; the question still remains open, however, as to which bed does the "pocketed coal" belong? Before the geological report of this basin shall be written for the final volume, some new facts may be obtained to throw additional light on the structure; at present, I am disposed to believe the coal here has an anticlinal structure, and is directly related to the bed below the Mammoth. I state this conclusion without attempting for the present to clear up the difficulties in the structure which I have suggested such a conclusion would lead to.*

The following section represents the strata included between the G and F beds in Tunnel No. 2.

Section No. 3, Columnar Section Sheet No. 1.—Portion of Nesquehoning Tunnel No. 2.

	Rock.	*Coal beds.*	*Total.*
1. Slate, hard with iron balls, . . .			
2. G COAL BED, ...		7′ 7″	to 7′ 7″
3. Slate, ...	31′ 5″		to 39′
4. Sandstone, ...	11′ 1″		to 50′ 1″
5. Slate, ...	30′ 6″		to 80′ 7″
6. RED ASH COAL BED, ...		14′ 4½″	to 94′ 11½″
Total thickness of rock, ...	73′		
Total thickness of coal beds, . .		21′ 11½	

Elevations of Coal Beds in Plane of Section No. 3.

Mammoth Bed.

North outcrop of Hell Kitchen basin, ...	1250
Bottom " " "	*250*

* A more detailed section of the structure represented by section No. 3 was constructed, and contained many facts procured after Cross section sheet No. I had been printed. It was at first expected to publish this section as a page-plate in this report; afterwards it was decided to postpone its publication until the final report.

South outcrop of Greenwood basin,	1115
North outcrop of Lansford basin, No. 2,	1120
Bottom of Lansford basin,	? ?
South outcrop of Lansford basin, No. 1,	1315

F or Lower Red Ash Bed.

North outcrop of Hell Kitchen basin,	1140
Bottom " " "	*685*
South " " " "	1075
North outcrop of Greenwood basin,	1065
Bottom " "	*870*
South " " "	1100
North outcrop of Lansford basin, No. 2,	1160
Bottom " "	? ?
South " " " No. 1,	*1240*

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5. Cross Section No. 4.

Through a point 330 feet west of Slope No. 3 Nesquehoning.

This section passes through the first lift gangway of Nesquehoning slope No. 3 at a point 330 feet west of the slope. The direction of the plane of section is S. 8° 30′ E. and is 1,625 feet west of No. 3 section plane. There are two features of special interest shown on this section; a local roll in the Mammoth bed on the south dip of the Hell Kitchen basin, and the commencement of the Coaldale anticlinal and Bull Run basin to the east of the Lansford basins, as proved by workings in the F or Lower Red Ash bed. The shaft anticlinal, which rises to the west between sections Nos. 2 and 3, falls in the same direction between 3 and 4.

The line defining the shape of the Mammoth bed in the eastern end of the section, surmises the existence of the Rhume Run overturned anticlinal. It is hard to arrive at any just conclusion as to what would be the probable shape of the Mammoth floor at this point. Wherever the bottom of the coal basins are worked, both in the Panther creek district and elsewhere, the coal bed has been almost always found in little basins and saddles; this is more particularly the case in basins which have high-pitching sides. In the case of this section, where the upper beds are found thrown into an overturned anticlinal, it is more than probable that the main Mammoth basin has some irregularities existing in its shape.

Elevations of Coal Beds in Plane of Section No. 4.

Mammoth Bed.

North outcrop of Hell Kitchen basin,	1270′
Bottom of Hell Kitchen (Greenwood) basin,	*230′*
Top of Shaft anticlinal,	1160′
Bottom of Lansford basin,	*100′*
Top of Coaldale anticlinal,	*810′*
South outcrop of Bull Run basin,	1320′

F or Lower Red Ash Bed.

North outcrop of Hell Kitchen basin (Slope No. 3,)	1185′
Bottom of Hell Kitchen basin,	*770′*
Top of Rhume Run overturned anticlinal,	*1170′*
Bottom of Greenwood basin,	*660′*
South outcrop of Greenwood basin,	*1230′*
North outcrop of Lansford basin,	1300′
Bottom of Lansford basin,	*420′*
Top of Coaldale anticlinal,	1220′
Bottom of Bull Run basin,	*1100′*
South outcrop of Bull Run basin,	1285′

G or Upper Red Ash Bed.

North outcrop of Greenwood basin,	1130′
South " " "	1180′
North outcrop of Lansford basin,	1290′
Bottom of Lansford basin,	*630′*
South outcrop of Lansford basin,	1235′

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6. Cross Section No. 5.

Through east end of workings of Tunnels Nos. 5 and 6 and Slope No. 4 and west end of Nesquehoning workings.

This section was constructed to show the connection between the Nesquehoning and Panther creek mine workings and the development to the west of the Coaldale anticlinal and Bull Run basin. It passes through the east end of the gangways from Tunnels Nos. 6 and 5 and Panther Creek slope No. 4 and the west end of the gangways of the Nesquehoning mines. The direction of the plane of section is S. 9° 30′ E. and is 3400′ west of No. 4 section plane. What has been said, as to the existence of a saddle in the main northern basin of section No. 4 would apply equally to the Lansford basin in both sections Nos. 4 and 5.

A notable instance of the pinching out of a coal bed is shown in this section in the Mammoth bed, on the northern side of the Coaldale anticlinal, where the coal bed thins rapidly between the 1st and 2nd lift gangways driven from Panther Creek slope No. 4, and pinches out entirely below the lower gangway.

Elevations of Coal Beds in Plane of Section No. 5.

Mammoth Bed.

North outcrop of Greenwood basin,	1320′
Bottom of Greenwood basin,	*—140′*
Top of Shaft anticlinal,	*780′*
Bottom of Lansford basin,	*—230′*
Top of Coaldale anticlinal,	*1290′*
Bottom of Bull Run basin,	*760′*
South outcrop Bull Run basin,	1390′

F or Lower Red Ash Bed.

South outcrop of Greenwood basin,	1250′
Bottom of Greenwood basin,	*190′*
Top of Shaft anticlinal,	*1145′*
South outcrop of Lansford basin,	*1300′*

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7. Cross Section No. 6.

Through Tunnels Nos. 5 and 6 and Slope No. 4 workings.

The plane of this section passes through Tunnel No. 6. The mouth of Tunnel No. 5 is 1200′ east of the plane and the strata cut by the tunnel are projected on to the eastern end of the section. The facts for determining the exact structure between Tunnels Nos. 5 and 6 were very few, the general features, however, of the anticlinals and basins are probably fairly represented by the section.

The bearing of the plane of section is S. 19° 45′ E., and the distance from the plane of section No. 5, 9,300′. There is less certainly known, about the geological structure under the central part of the Panther Creek valley between these two section planes than anywhere else in the district. There has been no extensive prospecting done, and there are few outcrops to throw any light upon the structure. In this area neither the Mammoth bed or the F or Lower Red Ash bed come to the surface between their most northern and most southern outcrops, along which both beds have been extensively mined as shown on Mine sheet No. II. From this fact any prospecting shafts or trial holes which may be sunk here, will have to be of considerable depth before passing through these two beds. The G or Upper Red Ash bed has been proven on both dips of the Shaft anticlinal in front of Tunnel No. 6. On the south dip a slope was driven to the depth of 100′. At the time the examination was made at this point the slope was full of water, so that no facts were obtained as to the thickness or character of the bed. Midway between the located outcrops of this bed, on either side of the anticlinal, a little basin of coal was proven by trial holes. This is regarded as belonging to the same bed, and if so, it is well to bear in mind this peculiarity of structure, that is the existence of a small basin on the crest of a large anticlinal, when considering the possibility of the summits of the anticlinals of the Mammoth bed being regular, as generally indicated by the sections in areas where the structure is more or less hypothetical.*

Another interesting peculiarity is illustrated by a comparison of these two sections. In section No. 6 the width of the Greenwood basin is much less than in section No. 5. The Shaft anticlinal in the Mammoth bed on the south side of the basin is lower in section No. 6 than in section No. 5. Where a basin narrows and is bounded on one side by an anticlinal, it has not been unusual for structural geologists to conclude that the anticlinal rises as the basin narrows. These sections show how unsafe it is to draw any conclusions as to the structure of the anthracite beds either from a general experience or from preconceived ideas of the laws governing structure.

The following columnar section shows the character of the strata between the F or Lower Red Ash bed and the Mammoth bed, in Shield's tunnel, which is 3380′ east of Tunnel

* A similar feature is observed in the center of the Bear Ridge anticlinal in the Mahanoy Coal Field.

No. 6. Shield's tunnel was driven from the water level gangway of Tunnel No. 6 to the Red Ash bed in order to work the latter bed.

Section No. 6.—Columnar Section Sheet No. 1.—Shield's Tunnel.

	Rock.	*Coal beds.*	*Total.*
1. RED ASH COAL BED, ...		15′	to 15′
2. Slate, ...	7′ 1″		to 22′ 1″
3. COAL and dirt, ...	8½′		to 22′ 9½″
4. Slate, ...	19′ 1″		to 41′ 10½″
5. Sandstone, ...	11′ 4″		to 53′ 2½″
6. Slate, ...	24′ 1″		to 77′ 3½″
7. COAL and dirt, ...	1′ 5″		to 78′ 8½″
8. Slate, ...	4′ 11″		to 83′ 7½″
9. Sandstone, ...	56′ 7′		to 140′ 2½″
10. Slate, ...	8½″		to 140 11″
11. Conglomerate and Sandstone, .	64′ 4″		to 205′ 3″
12. Slate, ...	7′ 9″		to 213′
13. Sandstone, ...	38′ 2½″		to 251′ 2½″
14. MAMMOTH COAL BED, ...		41′	to 292′ 2½″
Total thickness of rock, .	236′ 2½″		
Total thickness of coal beds, . .		56′	

In Tunnel No. 6 the measures are cut from a point below the G bed to the bottom of the Mammoth bed, a total vertical thickness of 665′, as follows:

Section No. 7, Columnar Section Sheet No. 1. Tunnel No. 6.

	Rock.	*Coal beds.*	*Total.*
1. Sandstone, ...	30′ 2″		to 30′ 2″
2. Slate, ...	7″		to 30′ 9″
3. Sandstone, ...	10′ 7″		to 41′ 4″
4. Slate, ...	6′ 6″		to 47′ 10″
5. Sandstone, ...	15′ 10″		to 63′ 8″
6. Slate, ...	4′ 1″		to 67′ 9″
7. COAL and dirt, ...	1′ 2″		to 68′ 11″
8. Slate, ...	55′ 11″		to 124′ 10″
9. Sandstone, ...	11′ 5″		to 136′ 3″
10. Slate, ...	1′ 3″		to 137′ 6″
11. COAL BED, ...		3′ 6½″	to 141′ ½″
12. Sandstone, ...	59′ 4″		to 200′ 4½″
13. G COAL BED, ...		5′ 8″	to 206′ ½″
14. Sandstone, ...	33′ 4″		to 239′ 4½″
15. Conglomerate and Sandstone,	23′ 3½″		to 262′ 8″
16. Sandstone and Conglomerate,	24′ 10″		to 287′ 6″

17. Slate,	4″		to 287′ 10″
18. Conglomerate,	16′ 3″		to 304′ 1″
19. Sandstone,	50′ 11″		to 355′
20. Slate,	11′ 4″		to 366′ 4″
21. Red Ash coal bed,		16′ 2″	to 382′ 6″
22. Sandstone,	9′ 2″		to 391′ 8″
23. Coal bed,		2′ 1½″	to 393′ 9½″
24. Slate,	40′ 4″		to 434′ 1½″
25. Slate,	11′ 4″		to 445′ 5½″
26. COAL and dirt,	1′ 5″		to 446′ 10½″
27. Sandstone,	63′		to 509′ 10½″
28. Coal bed,		1′	to 510′ 10½″
29. Conglomerate,	37′		to 547′ 10½″
30. Sandstone,	28′		to 575′ 10½″
31. Slate,	7′		to 582′ 10½″
32. Sandstone,	33′		to 615′ 10½″
33. Mammoth coal bed,		50′	to 665′ 10½″
Total thickness of rock,	587′ 4½″		
Total thickness of coal beds,		78′ 6″	

The constancy in the character and thickness of the strata over any considerable area is illustrated by a comparison of the lower part of this section, between the F or Lower Red Ash and the Mammoth beds, with the Shield's tunnel section. When it is remembered that it is sometimes difficult to determine the exact dip of the strata and the character of the rocks cut in a tunnel by the examination which is ordinarily made of the individual strata, it may be considered that these two sections are absolutely identical. The sandstone, stratum No. 5, in Shield's tunnel section is not shown in Tunnel No. 6 section. It would hardly be fair, however, to conclude that the sandstone noted in the former section was boldly marked from the including slate, and that absolutely no sandstone was found in the latter section in a similar position. From the fact that the sections were made at different times, even though they were measured by the same individual, what was noted as sandstone in one locality might have been called slate in the other. The same remark would apply to stratum No. 30 in Tunnel No. 6 section, which is indicated as sandstone and in Shield's tunnel section, stratum No. 11, as conglomerate and sandstone.

The strata cut on the south side of the Bull Run basin by Tunnel No. 5 are shown in the following section :

Section No. 5.—Columnar Section Sheet No. 1.—Tunnel No. 5.

	Rock.		Coal beds.		Total.	
1. Sandstone,	38′				to 38′	
2. Slate,	5′				to 43′	
3. Dirt seam,						
4. Slate,	40′	5″			to 83′	5″
5. COAL and dirt,	2′	4″			to 85′	9″
6. Slate,	20′	3″			to 106′	
7. Sandstone,	15′				to 121′	
8. Dirt seam,	1′	3″			to 122′	3″
9. Slate,	11′	9″			to 134′	
10. Conglomerate,	31′				to 165′	
11. Slate,	31′				to 196′	
12. Sandstone,	16′				to 212′	
13. Slate,	14′				to 226′	
14. COAL BED,			1′	5″	to 227′	5″
15. Slate,	7′	7″			to 235′	
16. G COAL BED,			7′		to 242′	
17. Sandstone and conglomerate,	34′				to 276′	
18. Conglomerate,	12′				to 288′	
19. Slate seam,						
20. Conglomerate,	52′				to 340′	
21. Slate,	19′				to 359′	
22. FOR RED ASH COAL BED,			11′	9″	to 370′	9″
23. Slate,	4′	6″			to 375′	3″
24. Sandstone,	4′	9″			to 380′	
25. Dirt seam,						
26. Sandstone,	9′				to 389′	
27. Dirt seam,						
28. Conglomerate,	12′				to 401′	
29. Slate,	5′	9″			to 406′	9″
30. Dirt seam,		6″			to 407′	3″
31. Slate,	23′	3″			to 430′	6″
32. Sandstone,	7′				to 437′	6″
33. Slate,	19′	6″			to 457′	
34. Dirt,	1′				to 458′	
35. Sandstone,	31′				to 489′	
36. Slate,	1′	6″			to 490′	6″
37. Sandstone,	83′	6″			to 574′	
38. Slate,	1′				to 575′	
39. FIVE FOOT COAL BED,			3′		to 578′	
40. Slate,	1′				to 579′	
41. Sandstone,	34′				to 613′	
42. Slate,		6″			to 613′	6″
43. Sandstone,	34′				to 647′	6″

MAMMOTH COAL BED.*	44. COAL, good, ...		7′	to 654′ 6″
	45. COAL, little benches, ...		6′	to 660′ 6″
	46. COAL, hard, ...		6′	to 666′ 6″
	47. Slate, ...	2′		to 668′ 6″
	48. COAL, gray, ...		3′	to 671′ 6″
	49. Slate, ...	10″		to 672′ 4″
	50. COAL, ...		8′	to 680′ 4″
	Total thickness of rock, . . .	627′ 2″		
	Total thickness of coal beds,		53′ 2″	

Elevations of Coal Beds in Plane of Section No. 6.

Mammoth Bed.

North outcrop of Greenwood basin, ...	**1378**
Bottom of Greenwood basin, ...	—*140*
Top of shaft anticlinal, ...	*440*
Bottom of Lansford basin, ...	—*330*
Top of Coaldale anticlinal, ...	*425*
Bottom of Bull Run basin, ...	*20*
South outcrop of Bull Run basin, ...	1375

G or Upper Red Ash Bed.

North outcrop of Greenwood basin, ...	1185
Bottom of Greenwood basin, ...	*555*
South outcrop of Greenwood basin, ...	1080
North outcrop of Lansford basin, ...	1095
Bottom of Lansford basin, ...	*355*
South outcrop of Lansford basin, ...	1120
North outcrop of Bull Run basin, ...	1145
Bottom of Bull Run basin, ...	*610*
South outcrop of Bull Run basin, ...	1320

F or Lower Red Ash Bed.

North outcrop of Greenwood basin, ...	1260
South outcrop of Bull Run basin, ...	1345

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8. Cross Section No. 7.

Through Tunnels Nos. 4 and 7 and Slope No. 1 workings.

The plane of this section passes through the center of the Nesquehoning railroad tunnel, and has a bearing S. 16° 20′ E. Its distance from section No. 6 is 5,000′. This section is one of the most interesting of those which have been constructed across the Panther Creek basins. The structural

*The total thickness of this bed given on Columnar section sheet No. I is 32′; the thickness of the individual benches of coal is not given on the sheet.

points shown, which are of special interest; are the regularity of the dip through the Locust Mountain, cut by the tunnel; the slight overturn of the shaft anticlinal near the mouth of the tunnel; the local roll on the southern side of the shaft anticlinal in front of the tunnel; the sharp flexure of the Coaldale anticlinal in bold contrast to the flat and broad flexure of the Summit Hill anticlinal; and finally the Summit Hill basin with the steep northern dip, which is so generally characteristic of many of the anthracite basins, and the flatter southern dip. Between sections Nos. 6 and 7 the shaft anticlinal in the Mammoth bed approaches Locust Mountain at the same time that it falls rapidly toward the west. The contour of the floor of the Mammoth bed on this anticlinal is shown on Mine sheet No. II, as defined from a section constructed by the Lehigh Coal and Navigation Company, in which the little roll at the mouth of the Nesquehoning tunnel was made to represent the shaft anticlinal. This same structure is shown on Mr. Rothwell's section. The company's section, from the Mammoth bed to the southern end of the tunnel, was taken to be authoritative, and was continued to the northern end from examinations made by the Survey. After the mine map was placed in the printer's hands, it was decided to make a resurvey of the southern end of the tunnel, and the structure shown on section No. 7 was made out, which is believed to be a more correct interpretation than that shown by the Rothwell or company sections, or the contours on the mine map which were based upon these sections.

The following sections represent the strata cut by the Nesquehoning railroad tunnel from the G bed down to the top of the Mauch Chunk Red Shale No. XI, a total thickness of 1493':

Section No. 8, Columnar Section Sheet No. I. Lansford Railroad (No. 7) Tunnel.

	Rock.	*Coal beds.*	*Total.*
1. G COAL BED,		15' 4''	to 15' 4''
2. Slate,	6' 4''		to 21' 8''
3. Sandstone,	102' 8''		to 124' 4''
4. Slate,	9'		to 133 4''

5. Sandstone,	79′		to 212′ 4″
6. Slate,	22′ 5″		to 234′ 9″
7. F coal bed,		19′ 8″	to 254′ 5″
8. Slate,	6″		to 254′ 11″
9. Sandstone,	32′		to 286′ 11″
10. Coal bed,		1′ 3″	to 288′ 2″
11. Slate,	64′ 3″		to 352′ 5″
12. Coal dirt,	7′		to 359′ 5″
13. Sandstone,	102′ 8″		to 462′ 1″
14. Slate,	11′ 6″		to 473′ 7″
15. Seam of coal dirt,	2′ 8″		to 476′ 3″
16. Sandstone,	35′ 4″		to 511′ 7″
17. E coal bed,		26′ 7″	to 538′ 2″
18. Slate,	7″		to 538′ 9″
19. Sandstone,	24′ 7″		to 563′ 4″
20. Slate,	4′ 2″		to 567′ 6″
21. Coal bed,		2′ 8″	to 570′ 2″
22. Slate,	10′		to 580′ 2″
23. Sandstone,	23′ 3″		to 603′ 5″
24. Slate,	7″		to 604′
25. D coal bed,*		11′ 3″	to 615′ 3″
26. Slate,	7′		to 622′ 3″
27. Sandstone,	8′ 5″		to 630′ 8″
Total thickness of rock,	553 11″		
Total thickness of coal bed,		76′ 9″	

The strata below this coal are represented in the following section, where B coal bed is the same as that noted in the above section as D.

Section No. 48, Columnar Section Sheet No. III.
Lansford Railroad (No. 7) Tunnel.

	Rock.	*Coal beds.*	*Total.*
1. B coal bed,			
2. Slate,	15′ 6″		to 15′ 6″
3. Conglomerate,	25′ 6″		to 41′
4. Seam,			
5. Conglomerate,	23′		to 64′
6. Sandstone,	9′		to 73′
7. Conglomerate,	9′		to 82′
8. Slate,	13′		to 95
9. Conglomerate,	2′		to 97′
10. Slate and sandstone, } 11. Coal, 1′ 6″, } 12. Slate and sandstone, }	27′		to 124′
13. Sandstone with pebbles,	13′		to 137′
14. Nut conglomerate,	10′		to 147′

*This bed is now considered to be the representative of the B or Buck Mountain bed.

15. Nut conglomerate, ...	11′		to 158′	
16. Sandstone, ...	2′		to 160′	
17. Nut and egg conglomerate, .	44′	6″	to 204′	6″
18. Slate, ...	2′		to 206′	6″
19. Nut and egg conglomerate, .	54′	6″	to 261′	
20. Large nut conglomerate, .	23′		to 284′	
21. Large nut conglomerate, . .	35′		to 319′	
22. Small nut conglomerate, . . .	11′	6″	to 330′	6″
23. Large nut conglomerate, . . .	47′	6″	to 378′	
24. Nut conglomerate, ...	12′		to 390′	
25. Seam, ...				
26. Nut conglomerate, ...	20′		to 410′	
27. Seam, ...				
28. Large nut conglomerate, . . .	20′	6″	to 430′	6″
29. Pea and nut conglomerate, . .	9′	6″	to 440′	
30. Pea and nut conglomerate, . .	4′	6″	to 444′	6″
31. Sandstone, ...	2′	6″	to 447′	
32. Sandstone, ...	21′	6″	to 468′	6″
33. Sandstone, ...	4′		to 472′	6″
34. Conglomerate, ...	3′		to 475′	6″
35. Sandstone, ...	3′	6″	to 479′	
36. Sandstone, ...	27′	6″	to 506′	6″
37. Egg conglomerate, ...	8′	6″	to 515′	
38. Slate, ...	2′	6″	to 517′	6″
39. Egg conglomerate, ...	4′	6″	to 522′	
40. Small nut conglomerate, . . .	5′		to 527′	
41. Egg conglomerate, ...	13′		to 540′	
42. Slate, ...	12′		to 552′	
43. Sandstone, ...	7′		to 559′	
44. Nut conglomerate, ...	6′	6″	to 565′	6″
45. Nut conglomerate, ...	2′	6″	to 568′	
46. Nut conglomerate, ...	12′		to 580′	
47. Nut conglomerate, ...	4′		to 584′	
48. Sandstone, ...	12′		to 596′	
49. Nut conglomerate, ...	10′		to 606′	
50. Saudstone, ...	8′		to 614′	
51. Sandstone, ...	6′		to 620′	
52. Sandstone, ...	4′		to 624	
53. Sandstone, ...	4′		to 628′	
54. Slate, ...	1′		to 629′	
55. Conglomerate, ...	18′		to 647′	
56. Olive slate, ...	14′		to 661′	
57. Sandstone, ...	12′		to 673′	
58. Large nut conglomerate, . . .	41′		to 714′	
59. Sandstone with pebbles, . . .	23′		to 737′	
60. Egg conglomerate, ...	25′	6″	to 762′	6″
61. Sandstone, ...	4′	6″	to 767′	
62. Slate, ...	6′	6″	to 773′	6″
63. Conglomerate and sandstone,	13′	6″	to 787′	
64. Slate, ...	5′		to 792′	
65. Conglomerate, ...	4′		to 796′	

66. Slate and sandstone,	8′	to 804′
67. Red sandstone and shale,	8′	to 812′
68. Gray compact sandstone,	15′	to 827′
69. Red shale and sandstone,	31′	to 858′
70. Conglomerate,	4′	to 862′
71. Red shale,	2′	to 864′
72. Slate and slaty sandstone,	20′	to 884′
73. Gray compact sandstone,	21′	to 905′
Mauch Chunk Red Shale No. XI, (Top.)		

This section shows minutely the structure of the Pottsville Conglomerate No. XII cut by the tunnel.

Elevations of Coal Beds in Plane of Section No. 7.

Mammoth Bed.

North outcrop of Greenwood basin,	1350
Bottom of Greenwood basin,	*105*
Top of shaft anticlinal,	*170*
Bottom of Lansford basin,	*—560*
Top of Coaldale anticlinal,	*770*
Bottom of Bull Run basin,	*—280*
Top of Summit Hill anticlinal,	**1480**
Bottom of Summit Hill basin,	*1180*
South outcrop of Summit Hill basin,	1530

F or Lower Red Ash Bed.

North outcrop of Greenwood basin,	1255
South outcrop of Bull Run basin,	1355

G or Upper Red Ash Bed.

North outcrop of Greenwood basin,	1205
Bottom of Greenwood basin,	*745*
South outcrop of Greenwood basin,	1105
North outcrop of Lansford basin,	1050
South outcrop of Lansford basin,	1125
Bottom outcrop of Lansford basin,	*230*

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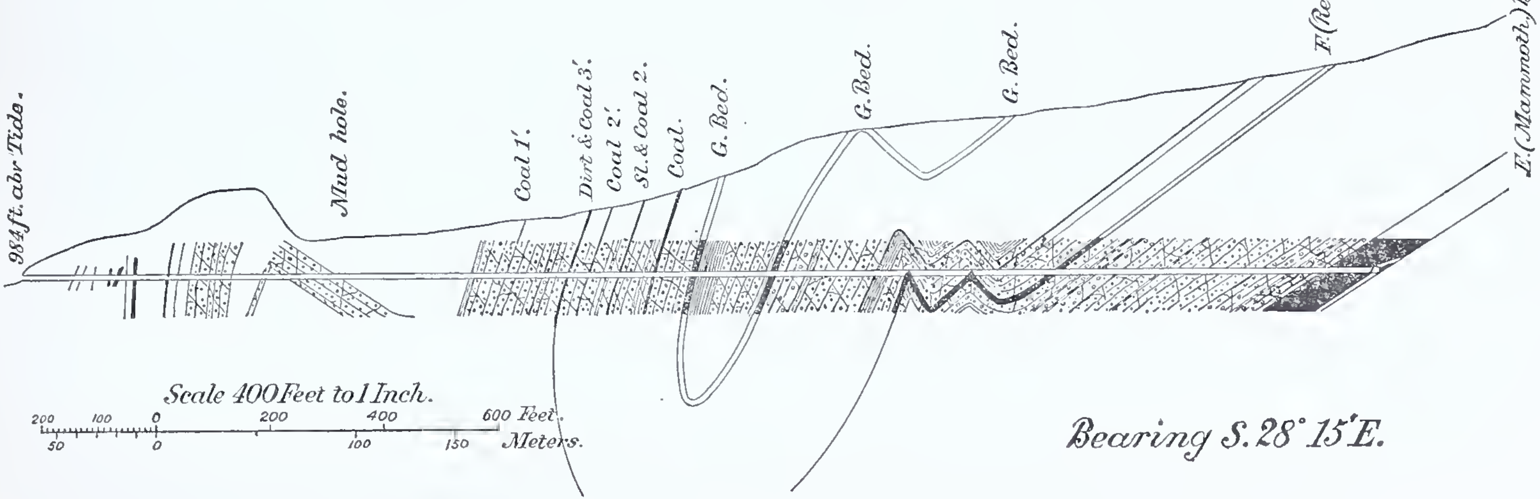
9. Cross Section No. 8.

Through Tunnels Nos. 8 and 9 and Slope No. 2 workings.

The plane of this section has a bearing S. 18° 15′ E., and passes through the southern end of Tunnel No. 9. The structure which was obtained by examinations in Tunnels Nos. 8 and 9 was projected directly on to the plane of this section. The main features are very much the same as those shown in section No. 7; with, however, considerable variation in the height, depth, and width of the anticlinals and basins. The section of Tunnel No. 9, on Cross section sheet No. II, was constructed by the company's engineers; and, as far as is known, is considered to be the accepted interpretation of the structure. About 400′ from the mouth of the tunnel the rocks were very much broken and twisted for a distance of 400′. In places no distinct stratification could be observed, and in the original notes of survey this part of the tunnel is represented as passing through a "*mud hole.*" Between the F and G Red Ash beds immediately in front of the Mammoth a small basin and anticlinal were represented. In the original notes of survey, observations on the strata were noted, which have not been included in the constructed section. These notes were plotted by Assistant A. W. Sheafer, and from them the accompanying section (See Plate II) was constructed. The prominent points of difference between the two sections are, the location of an anticlinal in a "mud hole" in the latter section, and the placing of two small basins and two anticlinals in the Lower Red Ash bed in front of the Mammoth. At the time that the field work in this basin was done by the Survey the mine workings of Tunnel No. 9 were on fire, and on this account it was impossible to make any examination of the rocks in the tunnel. Preference is given to the structure as shown by the section on the sheet, over that represented on the accompanying plate. On the north dip of the Summit Hill basin a peculiar squeezing out of the Mammoth bed is shown, the bed being cut out entirely—partly by the overlying, partly by the underlying rocks. In the section of Tunnel No. 8 the identification of the bed at the mouth of the tunnel was a matter of considerable importance, especially since the location of colliery No. 12, where the F or Red Ash bed is worked on the north side of the Lansford basin. It was important to know at what point the north outcrop of the F bed in the Lansford basin, and the south outcrop of the same bed in the Greenwood basin, pass around the shaft anticlinal, in order to know the

Geological Section through Tunnel No. 9, Panther Creek Coal Basin
Constructed from original notes in the possession of the Lehigh Coal and Navigation Company.



length of a gangway at a certain level, which should command a given lift along the bed.

The bed at the mouth of the tunnel has generally been considered to be the F bed. It is believed, however, that it is the G bed, and that the F bed passes over the top of the shaft anticlinal below the level of Tunnel No. 8. The outcrop of the F bed would appear to pass around the shaft anticlinal about a quarter of a mile east of breaker No. 12. The rocks underneath the G bed near the mouth of Tunnel No. 8 are thrown into a small anticlinal and basin directly over the general axis of the shaft anticlinal. These flexures may influence the structure of both the F and Mammoth beds at this point. It is impossible, however, to conclusively settle this point from the present developments. In section No. 8 the Mammoth bed is made to pass over the anticlinal without any irregularity in its contour.

A tunnel passes through the G bed near the bottom of the Greenwood basin and reveals a doubling over of the bed in the center of the basin, by which a small overturned anticlinal is produced, with a little basin on either side. From a study of the sections already constructed by the Survey in other districts, I am led to believe that, this kind of structure will be found to characterize many of the coal beds in the bottoms of the Panther Creek basins.

The following columnar section of the rocks met in Tunnel No. 9 was constructed shortly after the tunnel was driven. The Red Ash bed, on the north side of the Coaldale anticlinal, was not found in the tunnel. Its place would appear to be immediately under the last rocks before coming to the "*mud hole*" as shown on section No. 8.

Section No. 10,—Columnar Section Sheet No. I. Tunnel No. 9.

		Rock.	*Coal beds.*	*Total.*
	1. Rock,	148′ 6″		to 148′ 6″
G COAL BED.	2. COAL BED,		3′ 6″	to 152′
G COAL BED.	3. Slate,	4′ 9″		to 156′ 9″
G COAL BED.	4. COAL BED,		5′ 5½″	to 162′ 2½″
	5. Rock,	27′ 5″		to 189′ 7½″
	6. Slate,	1′ 8″		to 191′ 3½″
	7. COAL BED,		3′	to 194′ 3½″

	Rock.	Coal Beds.	Total.
8. Rock, ...	52′ 10″		to 247′ 1½″
9. COAL BED, ...		2′ 6″	to 249′ 7½″
Structure below this point uncertain.			
10. Slate,			
11. Conglomerate,			
12. Sandstone,			
13. Conglomerate,			
14. Slate,			
15. Sandstone,	} 212′ 6″		to 462′ 1½″
16. F COAL BED, ...			
17. Sandstone,			
18. Conglomerate,			
19. Slate,			
20. Coal dirt, ...	1′		to 463′ 1½″
Total thickness of rock, .	448′ 8″		
Total thickness of coal beds,		14′ 5½″	

The structure below the coal bed indicated as stratum No. 9 is very much confused, so that the distance of 212″ 6′ between the one foot bed of coal at the bottom of the section and this coal bed, may not represent the true thickness of rock perpendicular to the bed planes.

The following section of the strata passed through in the southern end of the tunnel was constructed at the same time as the above section. On account of the confusion in the rocks between the F and G beds, already indicated, the distance between these two beds shown by the section may prove to be excessive. Later sections, which have been constructed, make the thickness of this interval about 170′.

Section No. 9, Columnar Section Sheet No. I. Tunnel No. 9.

	Rock.	*Coal Beds.*	*Total.*
1. COAL BED, ...		3′ 4½″	to 3′ 4½″
2. Rock, ...	44′ 8″		to 48′ ½″
3. G COAL BED, ...		10′ 3″	to 58′ 3½″
4. Rock, ...	95′ 10″		to 154′ 1½″
5. Coal dirt, ...	4′ 7½″		to 158′ 9″
6. Rock, ...	101′ 1″		to 259′ 10″
7. F OR RED ASH COAL BED,		11′ 5″	to 271′ 3″
8. Rock, ...	41′ 6″		to 312′ 9″
9. COAL BED, ...		2′ 6″	to 315′ 3″
10. Rock, ...	214′		to 529′ 3″
11. Coal dirt, ...	8½″		to 529′ 11½″
12. Rock, ...	28′ 5½″		to 558′ 5″
13. MAMMOTH COAL BED, . .		50′	to 608′ 5″
Total thickness of rock, . . .	530′ 10½″		
Total thickness of coal beds,		77′ 6½″	

The strata in the north end of Tunnel No. 8, below the G bed, on the north side of the Greenwood basin, are shown by the following section.

Section No. 11, Columnar Section Sheet No. 1. Tunnel No. 8.

	Rock.	Coal Beds.	Total.
1. Sandstone,	15′		to 15′
2. G COAL BED,		10′	to 25′
3. Slate,	6′ 8½″		to 31′ 8½″
4. Sandstone,	32′ 1½″		to 63′ 10″
5. Dirt,	5′ 9″		to 69′ 7″
6. Conglomerate,	19′ 11″		to 89′ 6″
7. Slate and dirt,	24′ 4½″		to 113′ 10½″
8. Conglomerate,	11′ 6½″		to 125′ 5″
9. Slate and dirt,	12′ 10″		to 138′ 3″
10. Sandstone,	17′ 9″		to 156′
11. Conglomerate,	32′ 2″		to 188′ 2″
12. Slate,	13′ 5″		to 201′ 7″
13. Sandstone,	9′ 4″		to 210′ 11″
14. RED ASH COAL BED,		15′ 4″	to 226′ 3″
15. Slate,	4′		to 230′ 3″
16. Conglomerate,	43′ 1″		to 273′ 4″
17. Dirt,	1′ 4″		to 274′ 8″
18. Slate,	82′ 4″		to 357′
19. Sandstone,	9′		to 366′
20. Slate,	5′ 8″		to 371′ 8″
21. Sandstone,	30′ 5″		to 402′ 1″
22. Slate,	29′		to 431′ 1″
23. Sandstone,	6′ 4″		to 437′ 5″
24. Slate,	17′ 5½″		to 454′ 10½″
25. MAMMOTH COAL BED,		50′	to 504′ 10½″
Total thickness of rock,	429′ 6½″		
Total thickness of coal beds,		75′ 4″	

Elevation of Coal Beds in Plane of Section No. 8.

Mammoth Bed.

North outcrop of Greenwood basin,	1295
Bottom of Greenwood basin,	315
Top of Shaft anticlinal,	500
Bottom of Lansford basin,	—740
Top of Coaldale anticlinal,	705
Bottom of Bull Run basin,	—490
Top of Summit Hill anticlinal, (outcrop,)	1410
Bottom of Summit Hill basin,	955
South outcrop of Summit Hill basin,	1450

F or Lower Red Ash Bed.

North outcrop of Greenwood basin,	1205
North outcrop of Bull Run basin,	1120
South outcrop of Bull Run, (Foster's Tunnel) basin,	1360

G or Upper Red Ash Bed.

North outcrop of Greenwood basin,	1160
Bottom of Greenwood basin,	*920*
South outcrop of Greenwood basin,	1110
North outcrop of Lansford basin,	1020
Bottom of Lansford basin,	*120*
South outcrop of Lansford basin,	1070

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10. Cross Section No. 9.

Through Herring's Hollow, Tunnel No. 2, (Foster's Tunnel,) and Dry Hollow Slope.

This section is constructed through Herring's Hollow, No. 6 or Dry Hollow slope, and Tunnel No. 2 (Foster's Tunnel), and the pillar separating the Mammoth workings of Tunnel No. 8 on the east from the Greenwood Mammoth workings on the west. The bearing of the plane of this section is S. 15° 40′ E., and its distance from the plane of section No. 8, 5,925′. In the distance between these two sections an important change takes place in the geological structure. The anticlinal and basin which are cut in Foster's tunnel appear to be local rolls on the south side of the Bull Run basin. Although flexures of considerable importance at this tunnel, they seem to commence west of Tunnel No. 9, and end probably, somewhere in the vicinity of breaker No. 11.

The extreme eastern anticlinal and basin in this section have in each case been designated by the name Dry Hollow. In reality the Dry Hollow anticlinal is so intimately connected with the Summit Hill anticlinal that it is hard to make a distinction between them. By a study of the structure of the Mammoth bed, as shown by the contours on Mine sheet No. III, it will be observed that there is an important distinction to be made between these anticlinals. The Dry Hollow basin of section No. 9 dies out to the east before reaching section No. 8, and the Summit Hill basin of section No. 8 dies out to the west before reaching section No. 9. The anticlinal which separates the Dry Hollow basin from the Bull Run basin west, of section No. 9, would appear to be the same flexure as that which separates the Summit Hill basin from the Dry Hollow basin west between sections Nos. 8 and 9. Reference has already been made to the structure at this point in the description of the anticlinals and basins. (See pages 32 and 33.) Another pointof special interest, shown in this section, is the small anticlinal roll in the center of the Greenwood basin, as proven by the prospecting works in the F bed. This is apparently the same roll which was cut in Tunnel No. 8, and which is shown in section No. 10 in Tunnel No. 10. The intervals between the coal beds have been accurately measured in Foster's tunnel, and are shown in the following section.

Section No. 12.—Columnar Section Sheet No. I.—Tunnel No. 2, (Foster's.)

	Rock.	*Coal beds.*	*Total.*
1. Sandstone,			
2. COAL BED,		3′ 6″	to 3′ 6″
3. Rock,	73′		to 76′ 6″
4. COAL BED,		3′	to 79′ 6″
5. Rock,	30′		to 109′ 6″
6. COAL BED,		3′ 6″	to 113′
7. Rock,	110′		to 223′
8. RED ASH COAL BED,		7′ 6″	to 230′ 6″
9. Rock and slate,	90′		to 320′ 6″
10. COAL BED, (coal and slate,)		4	to 324′ 6″
11. Rock,	140		to 464′ 6″
12. COAL BED,		9′ 6″	to 474′
13. Rock,	110′		to 584′
14. MAMMOTH COAL BED,		25′	to 609′
Total thickness of rock,	553′		
Total thickness of coal beds,		56′	

Elevations of Coal Beds in Plane of Section No. 9.

Mammoth Bed.

North outcrop of Greenwood basin,	1180
Bottom of Greenwood basin,	*500*
Top of Shaft anticlinal,	*680*
Bottom of Lansford basin,	*—710*
Top of Coaldale anticlinal,	*500*

Bottom of Bull Run basin,	*—690*
Top of Foster Tunnel anticlinal,	*330*
Bottom of Foster's Tunnel basin,	*120*
Top of Dry Hollow anticlinal, (outcrop,)	**1298**
Bottom of Dry Hollow basin,	*545*
South outcrop of Dry Hollow basin,	**1395**

For Lower Red Ash Bed.

North outcrop of Greenwood basin,	1130
Bottom of Greenwood basin,	**960**
South outcrop of Greenwood basin,	1060
North outcrop of Lansford basin,	1050
Bottom of Lansford basin,	*—250*
North outcrop of Dry Hollow basin,	**1276**
Bottom of Dry Hollow basin,	*785*
South outcrop of Dry Hollow basin,	**1348**

11. Cross Section No. 10.

Through Tunnels Nos. 10 and 11.

Section No. 10 passes through Tunnels Nos. 10 and 11. The plane of the section has a bearing of S. 19° E. and is 4,775′ west of section No. 9. The points of special interest shown by this section, are the probable commencement of an anticlinal roll on the north side of the Dry Hollow basin, which to the west develops into the Tamaqua anticlinal and basin, and the overturn of the strata in Tunnel No. 10, between the south dip of the Red Ash bed in the Lansford basin and the small anticlinal in the center of the Greenwood basin, already referred to in the description of sections Nos. 8 and 9. The force which has overturned these strata has apparently squeezed out entirely the Red Ash bed on the south side of the Greenwood basin. No bed was cut at this point, representative of the F bed. The anticlinal roll in the center of the Greenwood basin was proven, on either side, to a considerable depth by a slope driven down on the bed. The force which has contorted the strata associated with the Red Ash bed in the Greenwood basin, seems to have affected the underlying Mammoth bed. Exploring works which have been made here, and which have been projected on to the plane of the section, show great irregularity in the lay of the Mammoth bed.

A trial hole was sunk 70′ to the G bed, near the center of the Dry Hollow anticlinal, a quarter of a mile in front of the mouth of Tunnel No. 11. A careful measurement was made of the rocks cut by Tunnels Nos. 10 and 11; they are shown in a vertical column as below:

Section No. 13—Columnar Section Sheet No. I—Tunnel No. 10.

		Rock.	*Coal beds.*	*Total.*
	1. G COAL BED,		10′	to 10′
	2. Sandstone,	83′		to 93′
	3. Slate, dirt, and coal,	10′		to 103′
	4. Sandstone,	16′		to 119′
	5. Slate,	10′ 6″		to 129′ 6″
	6. Sandstone,	42′		to 171′ 6″
	7. Slate,	20′		to 191′ 6″
	8. F COAL BED,		13′	to 204′ 6″
	9. Bone,	1′ 7″		to 206′ 1″
	10. COAL BED,		1′ 7″	to 207′ 8″
	11. Slate,	5′		to 212′ 8″
	12. Sandstone,	5′ 6″		to 218′ 2″
	13. Dirty coal,	1′		to 219′ 2″
	14. Slate,	12′		to 231′ 2″
	15. Sandstone,	2′		to 233′ 2″
	16. Slate with fire balls,	172′		to 405′ 2″
	17. Slate,	4′ 3″		to 409′ 5″
MAMMOTH COAL BED.*	18. COAL, soft and shelly,		3′	to 412′ 5″
	19. Dirt,	1′ 2″		to 413′ 7″
	20. COAL, good,		2′ 5″	to 416′
	21. Blue slate,	10″		to 416′ 10″
	22. COAL, slaty and bony,		3′ 5″	to 420′ 3″
	23. COAL, good,		3′ 5″	to 423′ 8″
	24. COAL, good,		3′ 5″	to 427′ 1″
	25. COAL, bony,		3′	to 430′ 1″
	26. COAL, good,		3′	to 433 1″
	27. Sulphur and dirt,	1′ 6″		to 434′ 7″
	28. COAL,		5′	to 439′ 7″
	29. Slate and coal,	3′		to 442′ 7″
	30. COAL, good,		2′ 5″	to 445′
	31. COAL, medium,		2′ 5″	to 447′ 5″
	32. COAL, slaty and bony,		2′	to 449′ 5″
	33. Slate,	1′ 6″		to 450′ 11″
	34. COAL, good,		4′	to 454′ 11″
	35. Slate and dirt,	2′		to 456′ 11″
	36. COAL, good,		3′	to 459′ 11″
	Total thickness of rock,	394′ 10″		
	" " " coal beds,		65′ 1″	

*The total thickness of this bed given on Columnar section sheet No. I is 50′ 2″; the thicknesses of the individual benches of coal are not given on the sheet.

Section No. 14—Columnar Section Sheet No. II—Tunnel No. 11.

		Rock.	Coal beds.	Total.
	1. Strata, ...	62′		to 62′
	2. Sandstone and soft rock, . . .	18′		to 80′
	3. Slate and sandstone, ...	131′		to 211′
	4. Slate, ...	24′		to 235′
	5. COAL BED, ...		3′	to 238′
	6. Slate seam, ...	——		
	7. Rock, ...	25′		to 263′
	8. Conglomerate, ...	75′ 6″		to 338′ 6″
	9. Dirt seam, ...	6″		to 339′
	10. Rock,..	28′		to 367′
	11. Slate, ...	13′		to 380′
	12. Strata, ...	157′		to 537′
	13. COAL BED, ...		5′	to 542′
	14. Rock,.	5′		to 547′
	15. COAL BED, ...		4′	to 551′
	16. Strata, ...	100′		to 651′
	17. Slate, ...	40′		to 691′
	18. RED ASH COAL BED No. 1, . .		12′	to 703′
	19. Strata, ...	29′ 11″		to 732′ 11″
	20. Strata, ...	62′ 9″		to 795′ 8″
RED ASH COAL BED No. 2*.	21. COAL, ...		1′	to 796′ 8″
	22. Dirt and soft coal, ...	1′ 1′		to 797′ 9″
	23. COAL, good and hard,.		4′	to 801′ 9″
	24. Bone and coal, ...	1′		to 802′ 9″
	25. COAL, good, ...		3′	to 805′ 9″
	26. Dirt, ...	6″		to 806′ 3″
	27. COAL, good, ...		6′	to 812′ 3″
	28. Dirt, ...	4″		to 812′ 7″
	29. COAL, good, ...		8″	to 813′ 3″
	30. Strata, ...	72′ 8″		to 885′ 11″
	31. COAL BED, ...		1′	to 886′ 11″
	32. Strata, ...	156′ 4″		to 1043′ 3″
	33. Strata, ...	21′ 11″		to 1065 2″
	34. MAMMOTH COAL BED, ...		57′ 9″	to 1122′ 11″
	35. Sandstone,.	52′ 9″		to 1175′ 8″
	36. Strata, ...	41′ 10″		to 1217′ 6″
	37. D COAL BED, ...		15′ 11″	to 1233′ 5″
	Total thickness of rock, . .	1120′ 1″		
	" " " coal bed,		113′ 4″	

Elevations of Mammoth Bed in Plane of Section No. 10.

North outcrop of Greenwood basin,.	1125
Bottom of Greenwood basin, ...	*410*
Top of Shaft anticlinal,.	*610*

* The thickness of this bed on Columnar section sheet No. II is 18′. The members of the bed are not given on the sheet.

Bottom of Lansford basin,	— *635*
Top of Coaldale anticlinal,	*300*
Bottom of Bull Run basin,	— *650*
Top of Dry Hollow anticlinal,	*635*
Bottom of Dry Hollow basin,	— *340*
South outcrop " " "	1370

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12. Cross Section No. 11.

Through Tunnel of Greenwood Slope No. 2 and Tunnel No. 11 workings.*

This section passes through the tunnel of Greenwood slope No. 2, which connects the Mammoth with the Red Ash workings, and has a bearing of S. 22° E. The distance of the plane of this section from that of No. 10 is 4900′.

Very few facts could be obtained in the center of the valley along the line of this section, so that the structure here is uncertain. The section through the tunnel of Greenwood slope No. 2, as well as the workings in the E or Mammoth bed from the same slope, clearly define the structure of the E, Cross Cut, and D beds (splits of the Mammoth bed) along the line of section. The structure, as represented upon the section, would be judged very fanciful, if it were not for the facts which prove it.

In the following sections, measured in Greenwood Tunnel, the character of the strata between the coal beds is not given.

Section No. 15—Columnar Section Sheet No. II—Greenwood Tunnel (mouth to Mammoth bed.)

	Rock.	*Coal beds.*	*Total.*
1. Strata,	98′		to 98′
2. Coal bed,		1′	to 99′
3. Strata,	180′		to 279′
4. G coal bed,		5′	to 284
5. Strata,	101′		to 385′
6. Coal bed,		4′	to 389′
7. Strata,	69′		to 458′
8. Coal bed,		1′	to 459′
9. Strata,	74′		to 533′
10. F (Red Ash) coal bed,		16′	to 549′
11. Strata,	75′		to 624′

* On Mine sheet No. III the line of the section is not drawn through the tunnel as it should be. This is an error in the printing.

12. COAL BED, ...		5′	to 629′
13. Strata, ...	126		to 755′
14. E (MAMMOTH) COAL BED, . . .		39′	to 794′
Total thickness of rock, . . .	723′		
" " coal beds, .		71′	

Section No. 16—Columnar Section Sheet No. II—Greenwood Tunnel (Mammoth (E) bed to C bed.)

	Rock.	Coal beds.	Total.
1. MAMMOTH COAL BED, ...		21′ 8″	to 21′ 8″
2. Sandstone, ...	15′ 4″		to 37′
3. Slate, ...	8′ 5′		to 45′ 5″
4. CROSS-CUT COAL BED, ...		13′ 3″	to 58′ 8″
5. Slate, ...	15′ 3″		to 73′ 11″
6. D COAL BED, ...		8′ 5″	to 82′ 4″
7. Strata, ...	42′ 1″		to 124′ 5″
8. Strata, ...	71′ 8″		to 196′ 1″
9. Strata, ...	35′ 4″		to 231′ 5″
10. C COAL BED, ...		8′ 5″	to 239′ 10″
Total thickness of rock, . . .	188′ 1″		
" " coal beds, .		51′ 9″	

Elevations of Mammoth Bed in Plane of Section No. 11.

North outcrop Greenwood basin, ...	1275
Bottom of Lansford basin, ...	— *680*
Top of Coaldale anticlinal, ...	*145*
Bottom of Bull Run basin, ...	— *615*
Top of Dry Hollow anticlinal, ...	*225*
Bottom of Tamaqua basin, ...	— *390*
Top of Tamaqua anticlinal, ...	— *165*
Bottom of Sharp Mountain basin, ...	— *535*
South outcrop Sharp Mountain basin, ...	1280

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13. Cross Section No. 12.

Along the Little Schuylkill River, showing the structure of the Pottsville Conglomerate No. XII in the Locust and Sharp Mountain Gaps at Tamaqua.

This section, which has been known by the name of Tamaqua, shows the structure on the eastern side of the Little Schuylkill river between the Mauch Chunk Red Shale outcrops north of Locust Mountain and south of Sharp Mountain respectively. A careful survey of this locality was made, and the facts obtained were incorporated with those already in the possession of the L. C. & N. Co., together with those contained in a section constructed by the First Geological Survey, and one by Mr. W. R. Symons of Pottsville. The general structure in all these sections is somewhat similar. Important modifications have, however, been made in the details, which make the exact position of the anticlinal and synclinal axes, and the depths of the basins, slightly different from those represented upon sections previously constructed. In 1852 and 1853 the examination which had previously been made by the First Geological Survey, was critically revised by a careful topographical and geological survey in the vicinity of Tamaqua, and a section was constructed, which is contained upon Plate 1 of the final report. At that time many of the coal beds were visible in openings which have since fallen shut, and many facts were obtained relating to the thickness and character of the coals, which it has been impossible for the present Survey to procure. The detailed description of the Tamaqua section is given in Vol. 2, Chapter 3, of the final report, to which the reader is referred.

The structure of the Mammoth bed, shown by the contours on Mine sheet No. III, has been defined from measurements taken directly from section No. 12. The structure, which is so clearly defined by both the section and map, needs no further explanation. In the final report a comparison will be made between this section and those above referred to. There is a total columnar thickness of rocks in this section above the A bed of 1903′, with 120′ of coal; below the A bed and down to what has been considered to be the top of the Mauch Chunk Red Shale, there is a vertical thickness of slate, sandstone, and conglomerate of 1165′. The character and thickness of these strata are given in the following columnar sections :

Section No. 17.—Columnar Section Sheet No. II.—Lansford Basin (Levan's Slope.)

	Rock.	*Coal beds.*	*Total.*
1. Slate and slaty sandstone, ...	35′		to 35′
2. Slate, ...	1′		to 36′

3. Slate and sandstone,	20′		to 56′
4. Coal slates,	160′		to 216′
5. COAL BED,		1′	to 217′
6. Strata,	63′		to 280′
7. COAL BED,		3′	to 283′
8. Strata,	106′		to 389′
9. COAL BED,		4′	to 393′
10. Strata,	158′		to 551′
11. COAL BED,		2′	to 553′
12. Slate,	13′		to 566′
13. COAL BED,		2′	to 568′
14. Strata,	128′		to 696′
15. COAL BED,		2′	to 698′
16. Slate,	13′		to 711′
17. COAL BED,		2′	to 713′
18. Strata,	38′		to 751′
19. JOCK COAL BED,		7′	to 758′
20. Strata,	92′		to 850′
21. COAL BED,		3′	to 853′
22. Strata,	84′		to 937′
23. COAL BED,		6′	to 943′
24. Strata,	46′		to 989′
25. COAL BED,		4′	to 993′
26. Strata,	55′		to 1048′
27. F COAL BED,		10′	to 1058′
28. Strata,	211′		to 1269′
29. E COAL BED,		24′	to 1293′
30. Sandstone,	45′		to 1338′
31. CROSS-CUT COAL BED,		5′	to 1343′
32. Strata,	48′		to 1391′
33. D COAL BED,		12′	to 1403′
34. Strata,	122′		to 1525′
35. C COAL BED,		8′	to 1533′
36. Strata,	175′		to 1708′
37. Coal.		——	
38. Strata,	55′		to 1763′
39. B COAL BED,		9′	to 1772′
40. Strata,	115′		to 1887′
41. A COAL BED,		16′	to 1903′
Total thickness of rock,	1783′		
" " coal beds,		120′	

Section No. 49—Columnar Section Sheet No. II—Pottsville Conglomerate No. XII in the Locust Mountain Gap.

	Rock.	*Coal beds.*	*Total.*
1. B COAL BED.			
2. Conglomerate,	115′		to 115′
3. A COAL BED,		16′	to 131′
4. Conglomerate,	40′		to 171′

5. Sandstone and nut conglomerate,	50′		to 221′
6. Conglomerate, at intervals, . . .	150′		to 371′
7. COAL, ...		trace.	
8. Conglomerate, at intervals, ...	115′		to 486′
9. Slate and slaty sandstone, ...	30′		to 516′
10. COAL, ...		trace.	
11. Conglomerate and sandstone, . .	215′		to 731′
12. Concealed, ...	110′		to 841′
13. Conglomerate, ...	40′		to 881′
14. Concealed. Some red shale, . . .	180′		to 1061′
15. Conglomerate, ...	20′		to 1081′
16. Red and olive shale and shaly sandstone, ...	120′		to 1201′
17. Conglomerate, ...	30′		to 1231′
18. Shale, ...	40′		to 1271
19. Sandstone, fine-grained and compact, ...	25′		to 1296′
Mauch Chunk Red shale No. XI.			
Total thickness of rock, . . .	1280′		
" " coal beds, . .		16′	

No limit has been assigned to top of the Pottsville Conglomerate No. XII in the Panther Creek basins.

Section No. 50—Columnar Section Sheet No. II—Pottsville Conglomerate No XII in the Sharp Mountain gap.

	Rock.	Total.
1. BUCK MOUNTAIN COAL BED.		
2. Conglomerate and sandstone, ...	120	to 120′
3. Concealed, ...	90′	to 210′
4. Nut conglomerate, ...	60′	to 270′
5. Concealed, ...	40′	to 310′
6. Conglomerate and sandstone, ...	40′	to 350′
7. Conglomerate and sandstone exposed at intervals, ...	170′	to 520′
8. Concealed, ...	60′	to 580′
9. Conglomerate, ...	45′	to 625′
10. Concealed, ...	165′	to 790′
11. Conglomerate, ...	40′	to 830′
12. Concealed. Some red shale, ...	110′	to 940′
13. Conglomerate, at intervals, ...	120′	to 1060′
14. Concealed. Some red shale, ...	60′	to 1120′
15. Conglomerate, ...	10′	to 1130′
Mauch Chunk Red shale No. XI.		

Elevation of Coal Beds in Plane of Section No 12.

Mammoth Bed.

North outcrop of Lansford basin, ...	970
Bottom of Lansford basin, ...	*—900*

Top of Coaldale anticlinal,	*—310*
Bottom of Bull Run basin,	*—510*
Top of Dry Hollow anticlinal,	*—340*
Bottom of Tamaqua basin,	—970
Top of Tamaqua anticlinal,	*—140*
Bottom of Sharp Mountain basin,	*—720*
South outcrop " " "	985

F or Lower Red Ash Bed.

North outcrop of Lansford basin (Levan's Slope,)	**900**
Bottom of Lansford basin,	*—630*
Top of Coaldale anticlinal,	*—30*
Bottom of Bull Run basin,	*—290*
Top of Dry Hollow anticlinal,	*—20*
Bottom of Tamaqua basin,	*—700*
Top of Tamaqua anticlinal,	*245*
Bottom of Sharp Mountain basin,	*—445*
South outcrop, " " "	950

Chapter IV.

1. Identification of the Panther Creek coal beds ; 2. Third Upper Red Ash bed ; 3. Second Upper Red Ash bed ; 4. First Upper Red Ash bed ; 5. Second Twin beds ; 6. First Twin beds ; 7. Jock bed ; 8. Washington bed ; 9 G or Upper Red Ash bed ; 10. F or Lower Red Ash bed ; 11. Mammoth bed ; 12. C bed ; 13. B (Buck Mountain) bed ; 14. A bed ; 15. Lykens Valley beds

1. Identification of the Panther Creek coal beds.

The identification of the coal beds in the Panther Creek basin is a geological problem, as important in its economical bearing as is the determination of the structure of the coal basins.

Every coal bed which has been cut has been carefully examined, a section of the bed has been measured, and the character of the coal and of the accompanying rocks compared with similar features at other openings, and in most cases a conclusion has been arrived at as to the relationship existing between the different beds.

The assistants of the First Geological Survey made a careful study of the coals in this basin, and conclusions were reached by them as to the identity of the beds, which seemed to be proven by the facts which could at that time be had. Some of these conclusions have been verified, others have been either disproved or have had some doubt thrown upon their correctness, by subsequent developments. The relationship of the beds is so entirely dependent upon an accurate solution of the geological structure of the coal basins, that any change in the cross-sections, rendered necessary from additional facts obtained through an extension of the areas mined, must necessarily affect the conclusions as to the identity of the beds.

This same question was one to which Mr. Rothwell, in his report on the Lehigh Coal and Navigation Company's property in 1869, gave considerable attention. In this report certain conclusions are indicated, if not actually stated as such, as to the identity of the beds. Some of them have since proved to be in error; yet it is due to the assistants of the First Survey, as well as to Mr. Rothwell, that credit should be given them for reaching so many conclusions, which have been proved by recent developments and which at the time they were made seemed to be bold hypotheses.

It is impossible within the scope of this report to give this question the consideration that its importance demands. A thorough discussion of all the points involved must be deferred until the final report.

The names assigned to the coal beds, on Columnar section sheets Nos. I, II, and III, are those which have been locally used. No attempt has been made to suggest a more systematic naming of the beds, or to change the name of a bed, where its identity with another bed similarly named is quite uncertain, or even actually disproved by the facts at present available.

In placing the sections on sheet No. I, the F bed in each section has been placed horizontally opposite the F bed in the adjoining sections, the most eastern section being on the left hand side of the sheet, and following in regular order toward the west end of the basin. This arrangement, while a convenient one for general reference, is probably not the best for a clear definition of the structure, from the fact that the sections measured on either side of the basin have been indiscriminately placed, whereas there are certain marked differences in the structure of the coal measures along Locust Mountain, and Sharp Mountain, which would seem to make it desirable to group the sections on either side of the basin by themselves. A comparison of the sections in this way will be made in the final report. At present it is only proposed to make general reference to the coal bed sections which have been measured, giving a description of the individual beds, in order to assist the engineer or geologist to a better understanding of the general conclusions which are indicated upon the sheets, and which have been made use of in obtaining the results contained in the tables, showing the amount and distribution of the available coal in the Panther Creek basin.

In consequence of the sinking of the basins of the Panther Creek valley toward the west, from Mauch Chunk to Tamaqua, the geologically highest and most recent coal beds are found in the vicinity of Tamaqua, where the basins are the deepest. An idea as to the distribution of the coal beds under the valley, may be had from the columnar sections placed on the margin of the mine sheets, which represent in a general way the coal measures and coal beds embraced within the area covered by each sheet.

2. *Third Upper Red Ash Bed.*

The highest coal bed, known to exist, is what has been named the *Third Upper Red Ash* bed, being the highest of the three beds composing the Upper Red Ash group.*

This coal is reported to have been found on the northern side of the Lansford basin immediately east of Tamaqua.

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* The names assigned to the groups of coal beds and to the individual beds of the sections accompanying Mine sheet No. III are those which are used in Rogers' final report. I consider that these names are not well applied and are confusing in comparing this section with others. This may be noticed in the series of sections placed upon the general map of the coal fields (Miscellaneous sheet No. II), where it will be observed that the names affixed to this section (section No. 10) have no correspondence, with the exception of the Mammoth bed, with those of the section of the coal measures in the Pottsville basin on the one side, or those designating the strata of the Shamokin basin on the other side. After the coal beds, throughout the whole region have been identified, as well as it may be possible, at the time of the completion of the Anthracite Survey, I hope to be able to propose some system for naming the beds which will render any two sections, however distant, readily comparable. What may prove to be the best system of designating the beds, it would be premature now to surmise. It is probable, however, that the simplest system which could be proposed, and which would steer clear of the difficulties at present encountered in making comparisons, would be to number the coal beds in regular order from the bottom up. If after such a system should have been adopted, other coal beds should be discovered, intermediate between those which have consecutive numbers, it might be well to give them the number of the bed next below, with a letter affixed as an index. Thus: If other coal beds should be discovered intermediate between coal beds Nos. 1 and 2, subsequent to the time when these latter beds should have been numbered, the lowest of these newly discovered beds could be called 1^a, the second 1^b, the third 1^c, &c.

It is but one foot thick, and dips at an angle of 80° S. It will probably never prove workable.

3. Second Upper Red Ash Bed.

This bed has been prospected on in the same basin, and is separated from the above bed by 63′ of rock. It is reported to be 3′ feet thick; nothing, however, is known as to whether it will prove workable.

4. First Upper Red Ash Bed.

This bed is separated from the second by 106′ of rock. It is reported to be 4′ thick, although not proved sufficiently, to suppose that this may be taken as its average thickness.

The coal beds from the Second Twin to the F or Lower Red Ash inclusive, comprise the Lower Red Ash group.

5. Second Twin Beds.

These beds are said to have been opened near water level at Tamaqua, and to have shown a thickness of 2′ each, with an interval of 13′ between; 158′ of strata intervene between them and the First Upper Red Ash bed.

6. First Twin Beds.

The section of these beds is similar to those of the Second Twin beds, 128′ of strata lying between the two. Nothing is certainly known as to either the permanent thickness of the beds, or the character of the coal.

The information which can be had, relative to all these coal beds, is very meager, and nothing is positively known as to whether the beds could be mined, or what they could be expected to produce. In estimating the total original coal contents of the Panther Creek basin it has been computed that these coals would produce 11,000,000 tons; if the Second Red Ash bed could be depended upon containing 1′ of clean marketable coal; the First Red Ash bed 2′; and the First and Second Twin beds 2′ each, throughout their entire areas. On account of the uncertainty of the information relating to these coals, this tonnage has not been included in the statement of the total contents of the basin.

7. *Jock Bed.*

This bed was cut in Greenwood tunnel No. 1 on the south side of the Lansford basin, and was at one time opened on its outcrop on the same side of the basin near Tamaqua. The bed has been considered to range between 6′ and 7′ thick. It is estimated that it contains 3′ of coal. It underlies 700+ acres on Mine sheet No. II, and 1245+ acres on Mine sheet No. III. If the bed can be depended upon containing 3′ feet of coal under these areas, its contents would amount in the aggregate to 18,153,490* tons of coal.

8. *Washington Bed.*

This bed has been located immediately under the Jock in Greenwood tunnel No. 1, at Tamaqua. It measures 3′ in thickness, and may be considered to contain at a minimum 1′ of clean coal. It underlies 1,083 acres on Mine sheet No. II and 1,796 acres on Mine sheet No. III, containing in the aggregate, 8,940,331* tons.

9. *G or Upper Red Ash Bed.*

This bed is geologically the highest coal bed which has been mined to any extent in the Panther Creek basin. It has been worked in a drift at Nesquehoning, on the north dip of the Greenwood basin; from Tunnel No. 1 on the south dip of the same basin; from Tunnel No. 9 on the north dip of the Bull Run basin; and from the old Levan's slope at Tamaqua, where a tunnel was driven from the foot of the slope in the F bed to the G bed. In the drift workings, above referred to, the bed measured 7′ thick, with 5′ of coal; and on the south dip of the Greenwood basin, in Tun-

*On account of the variable factors entering into the computation of the marketable contents of a coal bed, it would be quite sufficient, for all practical purposes, to state the aggregate tonnage of coal contained, in units of one hundred thousand or one million tons. I have, however, given the results exactly as computed, from the fact that in the tables published in Chapter VI all the factors used are recorded, and the accuracy of the Survey's computation can be better tested, or the result changed by a use of different factors, when the *exact result* obtained by the Survey is stated.

nel No. 1, 5′, with 3′ of coal. The bed seems to be badly rolled and pinched at other points on Mine sheet No. I, where it has been cut by Tunnels Nos. 1 and 2; so that, in computing the total original contents of the area contained on Mine sheet No. I, an average thickness was assigned to the bed of 5′, with only 2½′ of coal. On Mine sheet No. II the bed has been cut in Tunnels Nos. 5, 6, and 7. Its thickness at these points varies from 6′ in Tunnel No. 6 to 15′ in Tunnel No. 7, on the south dip of the Greenwood basin. The average thickness of the bed on this sheet has been taken to be 6′, with 3′ of coal. On Mine sheet No. III the bed has been cut in Tunnels Nos. 8, 10, and 11; in Greenwood tunnel, and in front of Levan's slope, as already stated. On this sheet the bed varies in thickness from 4′ at Greenwood tunnel to 10′ in Tunnel No. 8. The average for the sheet has been taken to be 5′, with 3′ of coal. The total original contents of this bed in the entire basin are estimated at 36,748,163 tons. The G bed underlies 59 acres on Mine sheet No. I; 1,544 acres on Mine sheet No. II; and 2,347 acres on Mine sheet No. III. In Tunnel No. 11, and No. 2 or Foster's Tunnel a bed was cut which has been locally named Red Ash Bed No. 1, lying between the G, and the F or Lower Red Ash beds. In the former tunnel this bed is reported to be 12′ and in the latter 7′ thick. It has been extensively mined from Tunnel No. 11; the average thickness of the bed through this mine being stated as 9′ with 4′ of coal. It is estimated that over 71,000 tons of coal have been taken from it, at this point. The true identity of the bed between the F, and what has been considered to be the G bed, at the western end of the basin, I do not think has been firmly established. It is questionable whether the name of "G bed" has been assigned to its true representative in this locality. Special reference will be made to this in the final report.

In computing the tonnages given in Table No. 1, this bed (Red Ash No. 1) is not considered, as it is not known over what area the bed can reasonably be expected to exist. The total original contents, which is there given, would be considerably augmented, if estimates had been made for this bed

10. F or Lower Red Ash Bed.

Next to the Mammoth, this has proved to be the most important bed which has been opened in the Panther Creek basin. It has been most extensively mined at Nesquehoning and Greenwood. It varies very much in thickness. The greatest *which has been recorded* is 17′ 7″, in the gangway driven west from Tunnel No. 11. On Mine sheet Nos. I & II this bed has been mined from Tunnels Nos. 1 & 2, slopes Nos. 2 & 3, and shaft No. 1. All of these workings are embraced within what is known as Nesquehoning colliery No. 3. The average thickness of the bed for this sheet has been taken as 13′, with 9′ of coal. So many measurements of the bed were obtained over a wide area, and on different sides of the several basins, on sheet No. I, that 9′ is believed to be the minimum thickness which could justly be assigned to the bed. It is probable that the estimate made of the coal contained on sheet No. II is too low, as the bed there has been assumed to contain on an average 5′ of coal. On this sheet the F bed has been mined from Tunnels Nos. 6, 7, and 9. Although the sections of the bed measured show as high as 9′ of coal, areas have been developed where the bed is either unworkable, from containing too much slate, or is pinched out. At Tunnel No. 6, where the bed has been extensively worked, a gangway was driven 3200′ in the bed, where the coal was faulted. What coal was found here was too poor to mine. In view of the possibility of the bed being faulted over other areas on this sheet, the average thickness of coal for the sheet has been taken to be 5′. On Mine sheet No. III, the F bed has been opened at Tunnels Nos. 8, 10, and 11, and at Greenwood. It has been found to be very regular throughout the Greenwood and No. 10 workings. An average of 9′ of coal has been assigned to the bed on sheet No. III. The estimated total original contents of the F bed for the entire basin is 130,379,486 tons, underlying 314 acres on Mine sheet No. I, 2,288 acres on sheet No. II, and 3,039 acres on sheet No. III. Up to the 1st of January, 1883, there had been mined from this bed 5,675,141 tons, so that at that time there remained 124,704,345 tons to be mined.

A number of sections of the bed have been measured in detail, and have been of great value in deciding what thickness of bed, and of coal contained, could be taken as an average for a colliery, or a part of a colliery. Of these sections, the following have been placed on Columnar section sheet No. III:

Section No. 35.—Greenwood Colliery.—3290′ east of Slope No. 1.

	Refuse.	Coal.		Total.
1. Bone,	2′		to	2′
2. Coal,		10′	to	12′
Total refuse,	2′			
Total coal,		10′		
Total thickness of bed,				12′

Section No. 40.—Tunnel No. 11.—West gangway.

	Refuse.	Coal.		Total.
1. Coal,		1′	to	1′
2. Dirt and soft coal,	1′ 1″		to	2′ 1″
3. Coal, good and hard,		4′	to	6′ 1″
4. Bone and coal,	1′		to	7′ 1″
5. Coal, good,		3′	to	10′ 1″
6. Dirt,	6″		to	10′ 7″
7. Coal, good,		6′	to	16′ 7″
8. Dirt,	4″		to	16′ 11″
9. Coal, good,		8″	to	17′ 7″
Total refuse,	2′ 11″			
Total coal,		14 8″		
Total thickness of bed,				17′ 7″

Section No. 41.—Tunnel No. 11.—1264′ west of Tunnel.

	Refuse.	Coal.		Total.
1. Coal,		1′	to	1′
2. Coal, soft,		1′ 1″	to	2′ 1″
3. Coal, good and hard,		4′	to	6′ 1″
4. Coal, (coal and bone,)		1′	to	7′ 1″
5. Coal, good,		3′	to	10′ 1″
6. Dirt,	6″		to	10′ 7″
7. Coal, good,		6′	to	16′ 7″
8. Dirt,	4″		to	16′ 11″
9. Coal, good,		8″	to	17′ 7″
Total refuse,	10″			
Total coal,		16′ 9″		
Total thickness of bed,				17′ 7″

Section No. 42.—Tunnel No. 9.—358′ west of Tunnel.

	Refuse.	Coal.		Total.
1. COAL, good, ...		1′	to	1′
2. Dirt and slate, ...	1′		to	2′
3. COAL, good, ...		2′	to	4′
4. Bone, ...	2′		to	6′
5. COAL, good, ...		2′ 6″	to	8′ 6″
Total refuse, ...	3′			
Total coal, ...		5′ 6″		
Total thickness of bed, . .				8′ 6″

Section No. 43.—Nesquehoning Tunnel No. 2.—2549′ west of Tunnel.

	Refuse.	Coal.		Total.
1. Bone and dirt, ...	1′ 6″		to	1′ 6″
2. COAL, good, hard, ...		4′ 9″	to	6′ 3″
3. Slate and bone, ...	6″		to	6′ 9″
4. COAL, hard, ...		3′ 6″	to	10′ 3″
5. COAL, soft, ...		2′	to	12′ 3″
6. Dirt, ...	6″		to	12′ 9″
Total refuse, ...	2′ 6″			
Total coal, ...		10′ 3″		
Total thickness of bed, . .				12′ 9″

The following table gives the average thickness of the F bed, and of coal contained, in the mines of the Panther Creek basin, commencing at the eastern end:

	Coal bed.	Coal contained.
Nesquehoning Colliery No. 3.		
Tunnel No. 1 S. Dip Hell Kitchen basin, ...	12	9
" " " overturned dip Hell Kitchen basin,	10	6
Tunnels Nos. 1 and 2, Shaft No. 1, Slope No. 2, N. and S. dips of Greenwood basin, ...	12	9
Tunnel No. 1 N. dip of Lansford basin No. 2, . . .	12	8
Tunnels Nos. 1 and 2 N. dips of Lansford basin No. 1,	17	12
Tunnel No. 2 S. dip of Lansford basin No. 2, ...	12	9
Slope No. 3 S. dip of Hell Kitchen basin, ...	14	10
No. 5 Colliery.		
Tunnel No. 5, N. dip of Bull Run basin, ...	10	4
No. 6 Colliery.		
Tunnel No. 6, S. dip of Greenwood basin, ...	9	7
No. 7 Colliery.		
Tunnel No. 7, S. dip of Greenwood basin, ...	9	6
No. 8 Colliery.		
Tunnel No. 8, S. dip of Greenwood basin, ...	9	4

No. 9 Colliery.		
Tunnels Nos. 9 and 3, N. dip of Bull Run basin, . .	9	7
No. 11 Colliery.		
Tunnel No. 11, N. dip of Sharp Mtn. basin (Red Ash bed No. 1), ...	9	4
Tunnel No. 11, N. dip of Sharp Mtn. basin (Red Ash bed No. 2), ...	13	9
Greenwood Colliery.		
Levan's Slope, S. dip of Lansford basin, ...	12	10

The following sections have been measured and reported of the Red Ash bed No. 1 in Tunnel No. 11:

Section No. 36.—Tunnel No. 11.—1500′ east of Tunnel.

	Refuse.	*Coal.*	*Total.*
1. Slate and coal,.	2′ 6″		to 2′ 6″
2. COAL, ...		1′	to 3′ 6″
3. Dirt and slate, ...	10″		to 4′ 4″
4. COAL, good, ...		4′ 3′	to 8′ 7″
5. Bone, ...	6″		to 9′ 1″
Total refuse, ...	3′ 10″		
" coal, ...		5′ 3″	
" thickness of bed,. . .			9′ 1″

Section No. 37.—Tunnel No. 11.—East gangway.

	Refuse.	*Coal.*	*Total.*
1. COAL (coal and slate), ...		2′ 2″	to 2′ 2″
2. COAL, soft, ...		1′ 6″	to 3′ 8″
3. Dirt.	8″		to 4′ 4″
4. COAL, good, ...		4′ 6″	to 8′ 10″
Total refuse,.	8″		
" coal, ...		8′ 2″	
" thickness of bed, . .			8′ 10″

Section No. 38, Tunnel No. 11. West gangway.

	Refuse.	*Coal.*	*Total.*
1. Slate and coal, ...	2′ 6″		to 2′ 6″
2. COAL, good, ...		1′	to 3′ 6″
3. Dirt and slate, . .	10″		to 4′ 4″
4. COAL, good and hard, *Bottom Bench*, ...		4′ 3″	to 8′ 7″
5. Bone, ...	6″		to 9′ 1″
Total refuse, ...	3′ 10″		
Total coal, ...		5′ 3″	
Total thickness of bed, . .			9′ 1″

Section No. 39, Tunnel No. 11.

	Refuse.	Coal.		Total.
1. Coal, good,		1′	to	1′
2. Dirt and slate,	1′		to	2′
3. Coal, good,		2′	to	4′
4. Bone,	2′		to	6′
5. Coal, good,		2′ 6″	to	8′ 6″
Total refuse,	3′			
Total coal,		5′ 6″		
Total thickness of bed,				8′ 6″

11. Mammoth Bed.

The most important of all the anthracite coal beds is what has been generally named, the Mammoth bed. Although it is found to undergo many changes in its thickness, and the alternation of its numerous coal benches with bony coal, slate, and sandstone, and as to the character of the coal which it will produce, which sometimes make it difficult to recognize it, yet it possesses many features and characteristics which are peculiar to it in almost every locality where it has been opened, and which make it the most easily* recognized geological horizon of any in the Carboniferous formation of the anthracite region.

This bed is sometimes found to exist as one bed of coal, the benches of which are not separated by more than two or three feet of slate or bony coal. These separating layers are more frequently only a few inches thick and vary very much as to number. This feature can be observed by glancing at the sections of the Mammoth bed on Columnar section sheet No. III. At one place in the old quarry workings at Summit Hill, where the bed measures 53′ 1″ thick, as many as 20 separate layers of slate and bony coal were contained in the bed, having an aggregate thickness of 12′ 10″. Some of these slate layers are continuous over

*This word is used here in a comparative sense. It is *easy* to trace some of the coal beds and associated strata through very limited areas.

In the bituminous coal fields of Pennsylvania, I find that it is easy to trace and identify any of the coal beds there as compared with the coal beds of the anthracite region. The Mammoth bed, however, of all the anthracite beds, is the one which can be most readily traced and identified from point to point over the entire coal fields. There may be other beds which are easier to trace locally, but certainly none can be more readily identified in all of the anthracite basins.

wide areas, and are oftentimes easily identified from point to point by the experienced miner. When studied in connection with the immediately associated coal benches, they form valuable clews, in determining in what part of the bed mining is being carried on. This is very important in some cases, where the separating slate becomes locally thickened and it becomes important to know whether the whole face of the coal bed is being mined, or whether there might not be another bench of good coal above or below those which are being worked. As a rule these widely separated coal benches or splits rarely number more than four, usually three, sometimes only two. In most parts of the region they are best known as the top, middle, and bottom splits of the Mammoth bed; in other cases they are called members or benches of the Mammoth, and sometimes have different names assigned to them, as in the case of the Wyoming basin, where the bottom split is called the Bennett, and the top the Cooper bed. In the Panther Creek basin, where the Mammoth bed undergoes this change, the different members are called E or Top Split, Cross-Cut or Middle Split, and D or Bottom Split. In this basin the name Mammoth is generally assigned only to what in reality is its top split. In Rogers' final report* reference is made to the tendency of the Mammoth bed to split into benches which become widely separated, and conclusions are reached which are quite untenable. Special reference will be made to this in my final report.

The Mammoth has been more extensively mined than any other of the Panther Creek coals. Eighty-eight (88) per cent. of the total coal removed has been from the Mammoth bed. The number of tons of coal mined from the several splits in the different parts of the basin may be ascertained by reference to the tables. The Mammoth bed underlies 495 acres on Mine sheet No. I; 2,817 acres on sheet No. II; and 3,532 acres on sheet No. III. It is estimated that this bed in the Panther Creek basin originally contained 572,370,108 tons of coal, and that 47,826,441 tons have been removed up to January 1, 1883, so that there still remains to be mined

* Vol. II, Page 70.

about 91.5 per cent. of the total original contents. This is a low estimate, in view of the fact that the Mammoth bed is supposed to contain only 23′ of coal on Mine sheet No. I, and 27′ on Mine sheets Nos. II and III. The thickest section of the Mammoth bed which has been measured in this district, or in fact as yet in the Anthracite Region, is 114′ 2″ at a point 4,017′ west of the inside slope of Tunnel No. 9 (Section No. 20, sheet No. III). This is an abnormal thickness and cannot be taken to represent what the bed can be expected to maintain over any area.*

Seventeen sections of the Mammoth bed have been carefully measured in the different mines of the Lehigh Coal and Navigation Co. to show the alternation of coal and slate in the bed. These sections have been constructed in vertical columns on a scale of 10′ = 1″, and may be found on Columnar section sheet No. III. They are as follows:

Section No. 18.—Nesquehoning Slope No. 3.—East side.

	Refuse.	*Coal.*		*Total.*
1. COAL, good,		15′	to	15′
2. Slate,	1′		to	16′
3. COAL, good,		9′	to	25′
Total refuse,	1′			
Total coal,		24′		
Total thickness of bed,				25′

Section No. 19.—Nesquehoning Slope No. 3.—5,751′ west of Tunnel.

	Refuse.	*Coal.*		*Total.*
1. COAL, good and hard,		9′ 2″	to	9′ 2″
2. COAL, soft,		8′ 5″	to	17′ 7″
3. Slate,	6′		to	23′ 7″
4. Dirt,	5′		to	28′ 7″
Total refuse,	11′			
" coal,		17 7″		
" thickness of coal,				28′ 7″

* There are other places in the coal fields where the bed has been considered to be even thicker than at this point, but in every case to which my attention has been called, where a greater thickness was claimed, the bed has been folded on itself. Mr. Oliver Rhodes, formerly operator of the Shenandoah colliery, states that a short distance east of the underground slope the bed measures on a horizontal 300′ thick. The top rock at this place dips 65° S. and the bottom rock 20° S. The actual thickness at this point perpendicular to the bedding may be fairly stated as between 150′ and 200′. It is believed, however, that the bed is lapped on itself at this point, which would account for its excessive thickness.

Section No. 20.—Tunnel No. 9.—4,017′ west of inside Slope.

	Refuse.	Coal.	Total.
1. COAL,		4′	to 4′
2. Blue slate,	2′		to 6′
3. COAL, good (SEVEN-FOOT BENCH),		14′	to 20′
4. COAL, poor (LITTLE BENCH),		14′	to 34′
5. COAL, good (FIVE-FOOT BENCH),		21′	to 55′
6. COAL, good (SLATY BENCH),		22′	to 77′
7. COAL, good (GRAY BENCH),		14′	to 91′
8. COAL, bony,		5′	to 96′
9. Slate,	6′ 6″		to 102′ 6″
10. COAL, good,		11′ 8″	to 114′ 2″
Total refuse,	8′ 6′		
" coal,		105′ 8″	
" thickness of bed,			114′ 2′

Section No. 21—Tunnel No. 9—4,129′ east of inside Slope.

	Refuse.	Coal.	Total.
1. COAL, good,		17′ 4″	to 17′ 4″
2. COAL, bony,		3′ 2″	to 20′ 6″
3. COAL, good (FIVE-FOOT BENCH,)		9 4″	to 29′ 10″
4. COAL, bony,		3′ 6″	to 33′ 4″
5. COAL, good,		5′	to 38′ 4″
6. Bone,	8″		to 39′
7. Slate,	1′ 4″		to 40′ 4″
8. COAL, good,		4′ 2″	to 44′ 6″
9. Slate,	1′ 6″		to 46′
10. Dirt,	3′ 2″		to 49′ 2″
Total refuse,	6′ 8″		
" coal,		42′ 6′	
" thickness of bed,			49′ 2″

Section No. 22—Tunnel No. 5—East gangway Slope No. 4.

	Refuse.	Coal.	Total.
1. COAL, good,		7′	to 7′
2. COAL, little benches,		6′	to 13′
3. COAL, hard,		6′	to 19′
4. Slate,	2′		to 21′
5. COAL, gray,		3′	to 24′
6. Slate,	10″		to 24′ 10″
7. COAL,		8′	to 32′ 10″
Total refuse,	2 10″		
" coal,		30′	
" thickness of bed,			32′ 10″

* See page 221.

Section No. 23—Tunnel No. 8—4,500′ east of Slope.

	Refuse.	Coal.	Total.
1. COAL, good,		12′	to 12′
2. Slate,	6′		to 18′
3. COAL, good, gray, clear,		4′	to 22′
4. COAL, good gray,		3′	to 25′
5. Bone,	1′		to 26′
6. Slate,	1′		to 27′
7. COAL, good,		5′	to 32′
8. Dirt,	5″		to 32′ 5″
9. COAL, good, hard,		3′	to 35′ 5″
Total refuse,	8′ 5″		
" coal,		27′	
" thickness of bed,			35′ 5″

Section No. 24—Tunnel No. 8—4,479′ east of Slope No. 5.

	Refuse.	Coal.	Total.
1. Blue slate,	1′		to 1′
2. Dirt,	4′		to 5′
3. COAL, good,		12′	to 17
4. COAL, good,		3′	to 20′
5. COAL, good,		9′	to 29′
6. COAL, good,		6′	to 35′
7. COAL, good,		4′	to 39′
8. COAL, good,		3′	to 42′
9. Bone,	1′		to 43′
10. Slate,	1′		to 44′
11. COAL, good,		5′	to 49′
12. Dirt,	5″		to 49′ 5″
13. COAL, good,		3′	to 52′ 5″
Total refuse,	7′ 5″		
" coal,		45′	
" thickness of bed,			52′ 5″

Section No. 25. Tunnel No. 8. 3,548′ west of Slope No. 5.

	Refuse.	Coal.	Total.
1. COAL,		3′	to 3′
2. Blue slate,	1′		to 4′
3. Dirt,	16′		to 20′
4. COAL, gray, clear, good,		11′	to 31′
5. Slate,	2′		to 33′
6. COAL, good,		3′ 8″	to 36′ 8″
7. Dirt,	1′ 2″		to 37′ 10″
8. COAL, good,		3′ 2″	to 41′
Total refuse,	20′ 2″		
Total coal,		20′ 10″	
Total thickness of bed,			41′

Section No. 26. Old Summit Hill Quarry.

	Refuse.	*Coal.*		*Total.*
1. COAL, with seams of slate and black dirt,		4'	to	4'
2. Slate,	1' 1"		to	5' 1"
3. COAL,		6"	to	5' 7"
4. Slate,	4"		to	5' 11"
5. COAL,		10"	to	6' 9"
6. Slate,	2"		to	6' 11'
7. COAL,		2'	to	8' 11"
8. Slate and bony coal,	2' 4"		to	11' 3"
9. COAL,		1' 7"	to	12' 10"
10. Slate,	5"		to	13' 3"
11. COAL,		1' 7"	to	14' 10"
12. Slate,	5"		to	15' 3"
13. COAL,		8"	to	15' 11"
14. Slate,	6"		to	16' 5"
15. COAL.		1' 6"	to	17' 11"
16. Slate and bony coal,	1'		to	18' 11"
17. COAL,		1' 1"	to	20'
18. Slate,	1"		to	20' 1"
19. COAL,		1 7"	to	21' 8"
20. Slate,	1"		to	21' 9"
21. COAL,		1'	to	22' 9"
22. COAL, bony,		10"	to	23' 7"
23. Slate and bone,	8"		to	24' 3"
24. COAL (LARGE OR SIX-FOOT BENCH,)		5' 9"	to	30'
25. Slate and bone,	11"		to	30' 11"
26. COAL,		1' 4"	to	32' 3"
27. Slate,	2"		to	32' 5"
28. COAL,		2'	to	34' 5"
29. Slate,	1"		to	34' 6"
30. COAL,		8"	to	35' 2"
31. Slate,	4"		to	35' 6"
32. COAL, (CLEAR BENCH,)		2' 6"	to	38
33. COAL, (GRAY BENCH,)		3'	to	41'
34. Slate,	4"		to	41' 4"
35. COAL, bony, } FOUR-FOOT SLATE,		6"	to	41' 10"
36. Slate, } FOUR-FOOT SLATE,	4"		to	42' 2"
37. COAL, bony, } FOUR-FOOT SLATE,		5"	to	42' 7"
38. Slate, } FOUR-FOOT SLATE,	2'		to	44' 7"
39. COAL, } FOUR-FOOT BENCH,		3' 4"	to	47' 11"
40. Slate, } FOUR-FOOT BENCH,	3"		to	48' 2"
41. COAL, } FOUR-FOOT BENCH,		1'	to	49' 2"
42. Slate,	1' 4"		to	50' 6"
43. COAL, THREE FOOT OR BOTTOM BENCH,		2' 7"	to	53' 1"
Total refuse,	12' 10"			
Total coal,		40' 3"		
Total thickness of bed,				53' 1"

Section No. 27.—Dry Hollow Slope.

	Refuse.	*Coal.*		*Total.*
1. COAL, good,		4′ 6″	to	4′ 6″
2. Dirt,	11″		to	5′ 5″
3. Slate,	1′ 4″		to	6 9″
4. COAL, bony,		2′ 1″	to	8′ 10″
5. COAL, good,		1′ 6″	to	10′ 4″
6. Slate,	1″		to	10′ 5″
7. COAL, good,		6′ 6″	to	16′ 11″
8. COAL, bony,		1′ 8″	to	18′ 7″
9. COAL, good,		2′ 7″	to	21′ 2″
10. COAL, bony,		1′	to	22′ 2″
11. COAL, good,		6′ 10″	to	29′
12. Dirt,	4″		to	29′ 4″
13. COAL, good,		7′ 4″	to	36′ 8″
14. COAL, shelly,		6″	to	37′ 2″
15. COAL, good,		1′ 5″	to	38′ 7″
16. Dirt,	2′ 2″		to	40′ 9″
17. COAL, soft,		5′ 1″	to	45′ 10″
18. Dirt,	7″		to	46′ 5″
19. COAL, good,		2′ 9″	to	49′ 2″
20. Dirt and slate,	2′ 7″		to	51′ 9″
21. COAL, shelly,		5′ 7″	to	57′ 4″
22. Dirt,	1′ 10″		to	59′ 2″
23. Slate,	4″		to	59′ 6″
24. COAL, good,		4′	to	63′ 6″
25. Slate,	2″		to	63′ 8″
26. COAL, good,		5′ 10″	to	69′ 6″
27. Slate,	6″		to	70′
Total refuse,	10′ 10″			
Total coal,		59′ 2″		
Total thickness of bed,				70′

Section No. 28.—Tunnel No. 9.—West gangway.

	Refuse.	*Coal.*		*Total.*
1. COAL, good,		2′	to	2′
2. Blue slate,	1′ 2″		to	3′ 2″
3. Dirt,	3′		to	6′ 2″
4. COAL,		9′	to	15 2″
5. Parting,	2″		to	15′ 4″
6. COAL,		5′	to	20′ 4″
7. Slate,	1″		to	20′ 5″
8. COAL,		4′	to	24′ 5″
9. Slate,	4′		to	28′ 5″
10. COAL, rough,		3′	to	31′ 5″
11. Slate,	4″		to	31′ 9″
Total refuse,	8′ 9″			
Total coal,		23′		
Total thickness of bed,				31′ 9′

Section No. 29.—Tunnel No. 9.—3,926′ west of inside Slope.

	Refuse.	Coal.		Total.
1. Coal,		4′ 6″	to	4′ 6″
2. Blue slate,	2′		to	6′ 6″
3. Coal, poor,		22′	to	28′ 6″
4. Coal, poor,		18′	to	46′ 6″
5. Coal, good,		9′	to	55′ 6″
6. Coal, good,		7′ 8″	to	63′ 2″
7. Slate,	4′ 8″		to	67′ 10″
8. Coal, soft,		4′ 10″	to	72′ 8″
Total refuse,	6′ 8			
Total coal,		66′		
Total thickness of bed,				72′ 8″

Section No. 30—Tunnel No. 10.

	Refuse.	Coal.		Total.
1. Coal, soft and shelly,		3′	to	3′
2. Dirt,	1′ 2″		to	4′ 2″
3. Coal, good,		2′ 5″	to	6′ 7″
4. Blue slate,	10″		to	7′ 5″
5. Coal, slaty and bony,		3′ 5″	to	10′ 10″
6. Coal, good,		3′ 5″	to	14′ 3″
7. Coal, good,		3′ 5″	to	17′ 8″
8. Coal, bony,		3′	to	20′ 8″
9. Coal, good,		3′	to	23′ 8″
10. Sulphur and dirt,	1′ 6″		to	25′ 2″
11. Coal, good,		5′	to	30′ 2″
12. Coal and slate,		3′	to	33′ 2″
13. Coal, good,		2′ 5″	to	35′ 7″
14. Coal, medium,		2′ 5″	to	38′
15. Coal, slaty and bony,		2′	to	40′
16. Slate,	1′ 6″		to	41′ 6″
17. Coal, good,		4′	to	45′ 6″
18. Slate and dirt,	2′		to	47′ 6″
19. Coal, good,		3′	to	50′ 6″
Total refuse,	7′			
" coal,		43′ 6″		
" thickness of bed,				50′ 6″

Section No. 31—Tunnel No. 10, inside Slope—East gangway, 3d level.

	Refuse.	Coal.		Total.
1. Bone,	1′		to	1′
2. Coal, good, clear,		7′ 3″	to	8′ 3″
3. Coal, good, gray,		3′ 3″	to	11′ 6″
4. Bone and slate,	1′ 9″		to	13′ 3″
5. Slate,	10″		to	14′ 1′
6. Coal, good,		3′ 10″	to	17′ 11″

	Refuse.	Coal.	Total.
7. Slate and dirt,	1′ 1″		to 19′
8. COAL, good,		3′	to 22′
Total refuse,	4′ 8′		
" coal,		17′ 4″	
" thickness of bed,			22′

Section No. 32.—Tunnel No. 11.—1843′ west of Tunnel.

	Refuse.	Coal.	Total.
1. COAL, good,		2′ 10″	to 2′ 10″
2. Slate,	8″		to 3′ 6″
3. COAL,		2′	to 5′ 6″
4. Bone and dirt,	2′ 4″		to 7′ 10″
5. COAL, good,		20′	to 27′ 10″
6. Slate,	4″		to 28′ 2″
7. COAL,		2′	to 30′ 2″
8. Slate,	2″		to 30′ 4″
9. COAL,		3′	to 33′ 4″
Total refuse,	3′ 6″		
" coal,		29′ 10″	
" thickness of bed,			33′ 4″

Section No. 33.—Greenwood Colliery, Slope No. 2.—650′ west of inside Tunnel.

	Refuse.	Coal.	Total.
1. COAL, soft,		3′	to 3′
2. Black dirt,	1′ 2″		to 4′ 2″
3. COAL, good,		2′ 6″	to 6′ 8″
4. Blue slate,	10″		to 7′ 6″
5. Slate and bone,	3′ 6″		to 11′
6. COAL, good,		3′ 6″	to 14′ 6″
7. COAL, good,		3′ 6″	to 18′
8. COAL, bony,		3′	to 21′
9. COAL, bony,		3′	to 24′
10. Sulphur,	1′ 6″		to 25′ 6″
11. COAL, good,		5′	to 30′ 6″
Total refuse,	7′		
" coal,		23′ 6″	
" thickness of bed,			30′ 6″

Section No. 34.—Greenwood Colliery.—Head of Tunnel east of Slope No. 1.

	Refuse.	Coal.	Total.
1. COAL,		8″	to 8″
2. Slate,	1′ 4′		to 2′
3. Bone,	1′ 5″		to 3′ 5″
4. COAL,		6′ 10″	to 10′ 3″

5. Bone,	4″		to	10′ 7″
6. Coal,		4′ 7″	to	15′ 2″
7. Dirt,	3′ 9″		to	18′ 11″
8. Coal, soft,		3′	to	21′ 11″
Total refuse,	6′ 10″			
" coal,		15′ 1′		
" thickness of bed,				21′ 11″

As in the case of the F bed, other sections in detail have been measured of the Mammoth bed. The average thickness of coal contained has been carefully estimated for each colliery and for parts of collieries from all the measurements which have been made. These thicknesses of the bed and coal contained, in each case, are stated in the following table :

Hacklebarney Tunnel.	*Coal bed.*	*Coal contained.*
Tunnel and inside slope N. and S. dips Hell Kitchen basin,	30′	24′
Nesquehoning Colliery No. 3.		
Tunnel No. 1, Slope No. 1, S. dip Hell Kitchen basin,	20′	16′
Tunnel Nos. 1 and 2, Shaft No. 1 and Slope No. 4, N. and S. dip Shaft anticlinal,	34′	22′
Tunnel No. 1, N. dip Lansford basin No. 1,	30′	20′
Slope No. 3, S. dip Hell Kitchen basin,	20′	16′
No. 4 Colliery.		
Slope No. 4, N. dip Bull Run basin,	42′	22′
No. 5 Colliery.		
Tunnel No. 5 and Slope No. 7, N. and S. dips Bull Run basin and N. dip Lansford basin No. 1,	21′	12′
No. 6 Colliery.		
Tunnel No. 6 and inside slope S. dip Greenwood basin,	50′	32′
No. 7 Colliery.		
Tunnel No. 7, S. dip Greenwood basin,	45′	24′
No. 8 Colliery.		
Tunnel No. 8 and inside slope S. dip of Greenwood basin,	53′	29′
No. 9 Colliery.		
Tunnel No. 9 inside slope and tunnels Nos. 3 and 4 N. dip Bull Run basin,	50′	25′
Summit Hill Colliery.		
Average for the area worked by this colliery,	60′	45′
No. 10 Colliery.		
Tunnel No. 10, inside slope and Greenwood Slope No. 2, S. dip and bottom of Greenwood basin,	52′	30′
No. 11 Colliery.		
Tunnel No. 11, N. dip of Sharp Mountain basin,	26′	12′
Tunnel No. 2 (Foster's,) N. dip Foster tunnel basin and S. dip Dry Hollow basin,	25′	14′

Greenwood Colliery.		
Levan's drift and Greenwood Slope No. 4, S. dip of Lansford basin, ...	25′	18′
Greenwood Slope No. 1, S. dip of Lansford basin,	20′	15′
Slope No. 2, S. dip of Greenwood basin, ...	37′	20′
Sharp Mountain Colliery.		
Slope, overturned N. dip Sharp Mountain basin, .	25′	16′

12. C Bed.

This bed has been mined to a very limited extent in the Panther Creek basin. The only place where it has been cut on sheet No. I is in Tunnel No. 1 at Nesquehoning. The average thickness of the bed for the entire sheet has been taken as 4′ 6″, with 3′ of coal· On sheet No. II it has been opened in Tunnels No. 6, 7, and 9. The average thickness on this sheet has been taken as 5′, with 3′ of coal. On sheet No. III the bed has been opened at Tunnels Nos. 8, 10, and 11, and at Greenwood tunnel and Levan's drift. More is known of this bed in the area covered by sheet No. III than elsewhere. In Tunnel No. 11, the bed has been named in the records of the Lehigh Coal and Navigation Company the D bed. At this point it has its maximum thickness of 17′, with a thickness of coal ranging from 11′ to 14′. Detail sections have been measured of this bed. The two following show the character of the bed in both the east and west gangway.

Section No. 44.—Tunnel No. 11.—East gangway.

	Refuse.	*Coal.*	*Total.*
1. Coal, good, ...		4′ 6″ to	4′ 6″
2. Slate, ...	2′ 6″	to	7′
3. Coal, soft, ...		4′ 6″ to	11′ 6″
4. Slate and dirt, ...	3′	to	14′ 6″
5. Coal, good, ...		2′ 6″ to	17′
Total refuse, ...	5′ 6″		
Total coal, ...		11′ 6″	
Total thickness of bed, . . .			17′

Section No. 45.—Tunnel No. 11.—1,084′ west of Tunnel.

	Refuse.	*Coal.*	*Total.*
1. Coal, ...		3′ 7″ to	3′ 7″
2. Coal, ...		5′ 5″ to	9′
3. Slate, ...	1′ 6″	to	10′ 6″
4. Coal, ...		5′ 5″ to	15′ 11″
Total refuse, ...	1′ 6″		
Total coal, ...		14′ 5″	
Total thickness of bed, . . .			15′ 11″

At Tunnel No. 8 the bed has been locally called the "Crack" and is 4′ thick; at the Greenwood tunnel it is 8′ thick. The average thickness for the sheet has been taken to be 11′, with 8′ of coal. It has been estimated that it underlies 638 acres on sheet No. I, 3,070 acres on No. II, and 3,729 acres, on sheet No. III, with a total original content of 128,256,560 tons; 136,890 tons have been taken out of the bed at Greenwood and Sharp Mountain collieries.

13. *B (Buck Mountain) Bed.*

This bed has been called in the Panther Creek Valley the Buck Mountain. It is to be questioned, however, whether what is known as the B bed everywhere in the Panther Creek basin is the true representative of the Buck Mountain bed. On Mine sheet No. I the bed has recently been shafted along its outcrop on the north dip of the Lansford basin No. 1, and on the north and south dips of the Mammoth anticlinal. The total length of outcrop which has here been explored is about two miles. The following are records* of a number of these trial shafts:

Trial Shaft No. 1.

Dip, 80° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		3′	to	3′
2. Dirt and slate, ...	6″		to	3′ 6″
3. Middle Bench, COAL, ...		2′	to	5′ 6″
4. Bottom Bench, COAL, ...		5′	to	10′ 6″

Trial Shaft No. 2.

Dip, 81° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		3′	to	3′
2. Slate, ...	3″		to	3′ 3″
3. Middle Bench, COAL, ...		2′	to	5′ 3″
4. Bottom Bench, COAL, ...		6′	to	11′ 3″

Trial Shaft No. 3.

Dip, 83° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		14′	to	14′
2. Dirt and slate, ...	1′		to	15′
3. Bottom Bench, COAL, ...		4′	to	19′

* These records were reported July 3, 1882, by Mr. J. C. Rutter, mining engineer. They show a good workable coal bed; the explorations, however, are hardly extended enough to prove that they represent an average thickness of bed over any considerable area.

Trial Shaft No. 4.

Dip, 85° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		3′	to	3′
2. Middle Bench, COAL, ...		6′	to	9′
3. Slate and bone, ...	5′		to	14′
4. Bottom Bench, COAL, ...		4′	to	18′

Trial Shaft No. 5.

Dip, 85° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		4′ 6″	to	4′ 6″
2. Middle Bench, COAL, ...		5′	to	9′ 6″
3. Slate, ...	6″		to	10′
4. Bottom Bench, COAL, ...		7	to	17′

Trial Shaft No. 6.

Dip, 85° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		3′ 6″	to	3′ 6″
2. Middle Bench, COAL, ...		4′	to	7′ 6″
3. Bone and slate, ...	4′		to	11′ 6″
4. Bottom Bench, COAL, ...		6′	to	17′ 6″

Trial Shaft No. 7.

Dip, 85° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		7′	to	7′
2. Bone and slate, ...	4′		to	11′
3. Bottom Bench, COAL, ...		6′	to	17′

Trial Shaft No. 8.

Dip, 85° N.	*Refuse.*	*Coal.*		*Total.*
1. Top Bench, COAL, ...		4′	to	4′
2. Bone and slate, ...	5′		to	9′
3. Bottom Bench, COAL, ...		6′	to	15′

Trial Shaft No. 9.

Dip horizontal, (in center of basin.)	*Rock.*	*Coal.*		*Total.*
1. COAL, ...		3′	to	3′
2. COAL, ...		6′	to	9′
3. Slate, ...	6″		to	9′ 6″
4. COAL, ...		7′	to	16′ 6″
5. Bone, dirt and slate, ...	17′		to	33′ 6″

In shaft No. 9 a thickness of 33′ 6″ was obtained. This, however, was right in the bottom of the Lansford basin, and is no doubt an excessive thickness. The maximum thickness of the bed in this locality might be stated at 18′.

The B bed has been mined in but two localities in the Panther Creek basin: in the Hacklebarney tunnel, where it had an average thickness of 12′, with 9′ of coal, and in Levan's drift, which is in the Locust Mountain gap, and is included in the Greenwood colliery, where its average thickness has been reported as 6′, with 3′ of coal. On the south dip of the Hell Kitchen basin the bed seems to be badly faulted. The bed was cut in the Nesquehoning R. R. tunnel, where it is 14′ thick, but only contains 2′ of coal. The bed was shafted on south of Tunnel No. 11, where it was found to contain 5′ of coal; also on Sharp Mountain near the river, where it contained only 2′ of coal. The average thickness assigned to the bed on Mine sheet No. I is 15′, with 10′ of coal; on sheet No. II, 8′, with 2′ of coal, and on sheet No. III, 6′, with 2′ of coal. This is probably an underestimate of the actual thickness of coal to be found in the bed in the areas covered by sheets Nos. II and III. With these thicknesses it has been estimated that the total original contents of the bed was 71,954,700 tons, of which but 115,347 tons have been taken out.

14. A Bed.

Geologically this is the lowest coal bed that has been worked in the Panther Creek basin. It has been mined on both the east and west sides of the river in the Locust Mountain gap. The horizontal distance between this bed and the B bed, on the west side, is 202 feet and, on the east 260 feet. This interval is filled mostly by conglomerate; the coal bed is also underlaid by conglomerate. The Locust Mountain drifts are closed, and it was impossible to examine the bed. It is reported however in the east drift to have measured as much as 16′ thick. The average for the entire workings would probably not exceed 10′ with 8′ of coal.

The A bed has been opened on the outcrop at Nesquehoning tunnel No. 1 and is reported to contain but 1′ of coal. It was also cut in the Nesquehoning R. R. tunnel but was found to be worthless. The average thickness of the bed for Mine sheet No. I has been taken as 3′ with 1′ of coal, for sheet II, 5′ thick with 2′ of coal, and for sheet

III, 7′ thick with 4′ of coal. On this basis the estimated original contents for the basin is 62,011,362 tons.

15. Lykens Valley Beds.

The question of the occurrence of these coal beds in the Panther Creek basin, with workable dimensions, is one of great uncertainty. Too few facts have been obtained upon which to base any conclusions. That the beds, which have been opened in the Locust Mountain gap and which are shown in the Tamaqua section are the true representatives of the Lykens Valley beds there seems to be no doubt, but that they extend under the entire basin or are as thick or thicker than in the gap it is impossible to say.

Chapter V.

1. Estimation of the Contents of the Anthracite coal beds; 2. New Method adopted by the Geological Survey; 3. Discussion of the errors involved in the New Method; 4. Development of the areas of the Coal beds in the Panther Creek Basin. (Miscellaneous Sheet No. I.)

1. Estimation of the Contents of the Anthracite coal beds.

In view of the fact, that Pennsylvania has no competitor in the market in the introduction of anthracite coal, it becomes a matter of vital interest and importance, to estimate accurately the coal contents of special tracts, of the individual basins, and of the entire region. In the past, this question has been one purely of conjecture and speculation, as regards the entire region. As the Geological Survey shall progress, facts will be obtained for solving it by a careful study and measurement of the geological features of each coal basin, as it shall be mapped. If the actual area of the coal beds in the various foldings which they are found to undergo can be measured, and the average thicknesses of the beds can be determined, it becomes a simple mathematical problem to ascertain the number of tons of coal underlying a certain area. The individuals and companies mining coal have careful measurements of the thicknesses of their several beds and know very nearly how much coal underlies each acre of surface of their property, and how much of this coal they can reasonably hope to mine and ship to market. This applies more particularly to the areas which have been actually proven by mining developments. Many of the operators owning large estates, which are only being worked by scattered mines, have never connected their mine surveys in such a form as to be able to define, with a reasonable degree of accuracy, the probable geological structure of their property; and, therefore, cannot estimate the surface area of their estate underlaid by coal, the area of the coal beds, or the total tonnage of the area containing coal. Until the total area of a coal basin is known, and a careful estimate of the average thickness of coal under a unit of area is made, it is premature to attempt to obtain its total contents, or to surmise its ultimate exhaustion. In most of the estimates which have been made of the coal tonnage of special tracts, the results have been obtained, by multiplying the area of the tract, which is known to be underlaid by coal beds, by the average number of tons, which past experience has shown, could be obtained from some unit of area. In the more careful estimates, such a computation has been made for each individual bed; the total tonnage of the tract being arrived at, of course, by the addition of these individual results. Few of these estimates have taken into account the greater or less amount of coal under a unit of surface, due to a varying degree of dip in the coal beds. Other things being equal, an acre of surface underlaid by a coal bed having a high dip, would contain a greater number of tons of coal, than if underlaid by the same bed, having a low dip or when nearly horizontal.

The excess of tonnage, due to high dips and foldings of the beds, has been assumed as equal to the number of tons of coal which would be contained in the areas where the bed is crushed and too poor to mine, faulted, or entirely pinched out. The methods which have been used in foreshadowing future production have, probably, been the best for deducing the most practical results from the facts which have been available; too many unknown and varying factors, dependent upon the conditions and methods of mining, enter into the computations to make the results of permanent value.

This method was first described in a paper read at the Philadelphia meeting of the American Institute of Mining Engineers, February, 1881, entitled "A New Method of Mapping the Anthracite Coal Fields of Pennsylvania;" it was afterwards referred to in greater detail, as in this report, in a paper read before the Engineer's Club of Philadelphia, March 17th, 1883, entitled "New Method for Estimating the Contents of Highly Plicated Coal Beds, as applied to the Anthracite Fields of Pennsylvania."

2. *New Method adopted by the Geological Survey.*

The plan which has been adopted by the Survey is to obtain the following values: 1. The surface areas underlaid by coal. 2. The actual surface areas of the coal beds. 3. The average workable thickness of the coal beds in special areas. From these values can be estimated: 4. The number of tons of coal contained in any given surface area. 5. The number of tons of coal contained in any given bed area. The greatest element of uncertainty which enters into this problem, and which will affect its ultimate accuracy, is the difficulty of assigning an average thickness to a coal bed over any considerable area. The estimates of coal tonnage, therefore, will be only provisional, and will have to be changed as new facts shall be obtained in mining, to change the thickness of the bed which has been used in the computation. The areas will be classified as those underlaid by regular dipping coal beds, and those underlaid by overturned coal beds. This is an important distinction, since the coal in overturned beds is generally too badly crushed and too dirty to be workable.* The former areas will be divided into small sections clearly defined on the

*The Red Ash coal bed immediately above the Mammoth is overturned in the Hell Kitchen basin south of Nesquehoning. The coal has been mined from the bed on the inverted dip. This, however, is an exceptional case. (See sections Nos. 2, 3, and 4, Cross section sheet No I, and Mine sheet No. I.)

mine sheets; so that, any portion of the estimates may be verified or changed, in accordance with mining developments which shall be made, in districts which are at present unworked. It is proposed to place the surface areas underlaid by coal and the actual area of a coal bed only on the sheets in the miscellaneous series, which will give the developments of the coal basins. The accuracy of these results are solely dependent upon the solution which the Survey will make of the geological structure. This solution, in areas where little mining is done, will no doubt be modified very much in detail by future developments; but the modification will probably never be so great as to materially affect the actual area of the coal bed given; so that, all the estimates placed upon the sheets may be considered more or less permanent. The results of the computation of the actual tonnage will be alone stated in the preliminary report, together with the coal bed thicknesses which have been used. It is readily perceived that this plan furnishes a basis for permanent estimates; as additional facts shall be obtained relating to bed thicknesses, they can be incorporated into the Survey estimates and the results changed.

To make this plan practical, it is necessary to command three classes of facts:

First. A map showing the outcrop of the coal bed; *Second.* Cross sections of the coal beds; and *Third.* Columnar sections of the coal beds, showing how much of each bed may be considered commercial coal, or that which, if taken out of the mine, can be marketed for fuel. These facts will be furnished by the mine, cross section and columnar section sheets which are being constructed.

If the surface of a coal bed, which has been contoured, shall be developed or ironed out into a horizontal plane. allowance will be made for every degree of dip which the bed possesses in its true position, and the real area of the bed on the flat will be shown. From the very nature of surfaces of double curvature, such as a sphere, ellipsoid, paraboloid, etc.; or of irregular surfaces, such as any section of the earth's surface; or of coal beds, such as those of the highly flexured anthracite basins, it is an impossibility to flatten them out graphically into plain surfaces having *absolutely* equivalent areas; it can, however, be done with sufficient approximation to answer all practical purposes.

In the case of the anthracite beds, it was desirable to devise some method of construction by which the area of a bed, whose surface was shown on a map by contour curves, could be approximately obtained by a graphical method. This may be accomplished in the following way: Vertical cross-sections of the contoured bed are constructed perpendicular to the general direction of the coal basins and at equal distances apart. The restored position of the coal bed is constructed along the line of section at such places where the bed has been eroded; so that, the line showing the position of the bed between the terminal outcrops is unbroken. Each one of these individual section lines, along the floor of the coal bed, is then developed into a straight line; the development of the sections being made on either side of its intersection, with a vertical plane drawn in the direction of the coal basin, and as nearly as can be, along the center of the area to be developed. The developed position of the outcrop of each section is then connected by irregular lines, with the corresponding points of outcrop on adjoining sections. In this way the developed areas of the coal beds having regular dips, and overturned dips respectively, and the area of the coal bed which has been eroded, are inclosed.

The position assumed for the vertical plane is purely arbitrary. No matter what may be the relative position of the developed sections, the resulting areas will in every possible case be the same.

If the points of outcrop on the section lines should be connected by straight lines, the area between any two sections would represent a trapezoid; the sides formed by the section lines would always remain the same length and the same vertical distance apart, and the area of the trapezoid would remain constant, no matter what should be the relative position of the section lines, so long as they remained parallel, and the same distance apart. The sections are best developed on either side of a central plane passing through the coal tract, and then the shape of the developed area of the coal bed will most nearly resemble the shape of the tract.

3. *Discussion of the Errors Involved in the New Method.*

This plan seems to be practical, and to furnish results of sufficient accuracy, when it is remembered that the bed area is but one of the factors used in determining the ultimate tonnage, and that the number of the other factors that have to be taken into consideration, such as the thickness of the coal bed, and its continuity over any considerable area, are in themselves extremely variable.

Mr. Arthur Winslow, under my direction, has carefully considered the errors in the method, and has formulated them with considerable care. The results of his study are concisely stated by him in the following description.

It is perceived that by this method of determining the developed area, no account is taken of any curvature or irregularity of position which the surface of the bed may have between the lines of section. This error is inversely proportional to the number of sections which are constructed. If an infinite number of sections were constructed at an inappreciable distance apart, this special error would vanish. In order to obtain the amount of error, due to this cause, an actual test was made in the case of the eastern end of the Panther Creek basin. This basin was selected from the fact that the beds are highly folded, and the basin sinks probably more rapidly, in the direction of its axis than any other basin in the coal region, of a similar size. The bottom of the Mammoth basin at Hacklebarney Tunnel has been estimated to be 1,140 feet above tide. At section No. 2, which is 10,900′ west of section No. 1, the bottom of the Mammoth basin is 200 feet above tide, showing an average rate of fall of 8.6′ per hundred. The sections were first constructed across this basin 1,600′ apart for a distance of 18,000′ from the eastern extremity; they are numbered on the sheet 1, 1; 2, 2; . . . 12, 12. These sections were developed by the method just described, and the area of the developed surface of the bed was found to be 67,097,600 square feet; similar sections were then constructed across this same area and intermediate between the others; these are numbered 1′, 1′; 2′, 2′; . . . 11′, 11′. These latter sections were then developed in conjunction with the others, making the distance 800′ between each section, and the developed area thus obtained amounted to 66,867,200 square feet. This shows the difference between the two areas, one determined by sections 1,600′ apart, the other by sections 800′ apart, to be 230,400 square feet; or in other words, the percentage of difference between the two areas would be .344 % of the original area; the probable error by the use of 1,600′ sections would amount to about (.344×2) $\frac{2}{3}$ of one per cent.

This is, no doubt, a maximum difference, since the irregularities of the basins are at a maximum; if, however, this error should be the same in similar basins throughout the whole coal fields, by the use of 1,600′ rather than 800′ sections, the total error of bed area would be two square miles, which, though considerable in itself, is small as compared to the errors which may be introduced into the calculation by the other and more variable factors noted.*

In all the developements which will be made of the coal basins, sections 1,600′ apart will be used, on account of the time which would be consumed in constructing them closer together. There are other errors in this method of construction which, while of no importance as far as vitiating the practical value of the results, are worthy of theoretical consideration.

Mr. Winslow's demonstration is as follows:

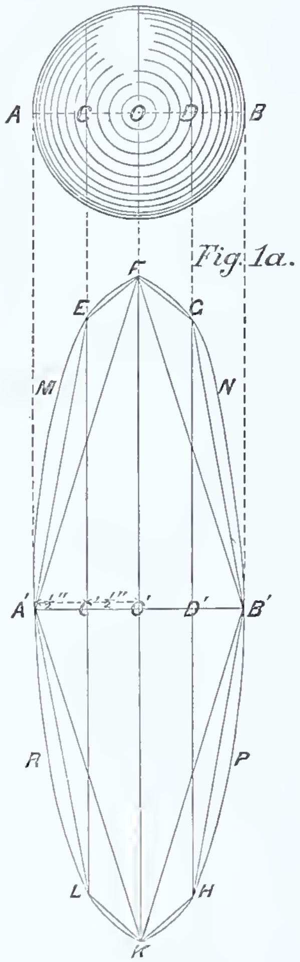
Take first the case of a sphere, which is represented by Fig. 1. Passing three parallel sections through this sphere perpendicular to a diameter A B, in such a manner that one passes through the center O and the others are tangents to the sphere at A and B respectively, the lengths of the peripheries of the sections at A and B will be zero, (since a plane tangent to a sphere touches the surface of the sphere

*The difference between the surface area underlaid by coal in this part of the Panther Creek basin and the area of the surface of the coal bed is 27,669,760 square feet, the surface area being only equivalent to 41% of the developed area, the average percentage of the entire coal region would certainly be very much below this, so that the error would not be as great as that we have supposed.

Figures to illustrate method of development of the Surface areas of Coal Beds.

Fig. 1.

Fig. 2.



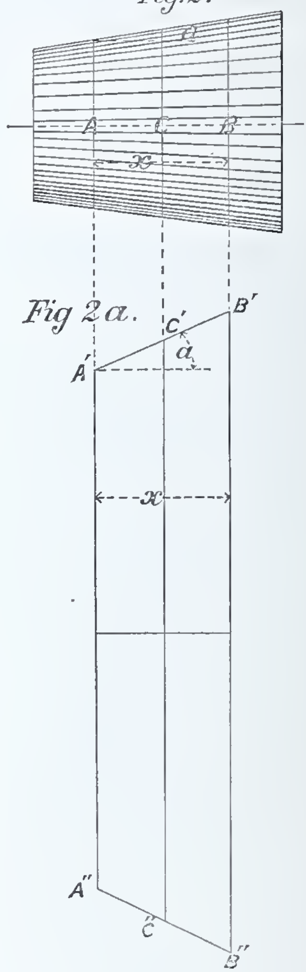
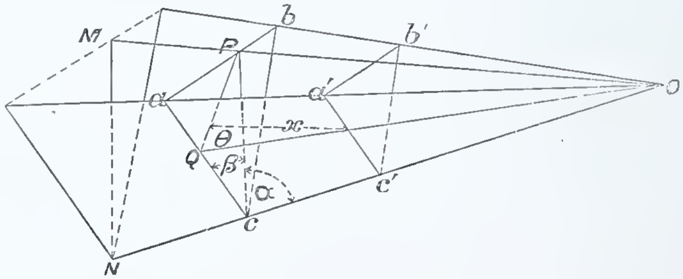


Fig. 3.



at only one point,) and the line of intersection of the plane through O with the surface of the sphere will be the circumference of a great circle. Laying these lengths off at the same distance (r, the radius of the sphere,) apart in the proposed manner, and joining the extremities, figure A′ F B′ K, Fig. 1a is formed. If section planes are now passed through the sphere at distances apart equal to $\frac{1}{2}$ r through A, C, O, D and B, the area obtained in a similar manner would be represented by the angular figure A′ E F G B′ H K L, Fig. 1a, whose area is greater than that derived in the first case. Continuing in this manner to increase the number of sections, the plotted area constantly increases until the number of sections is infinite, when it reaches its maximum and becomes a curved figure, A′ M F N B′ P K R, Fig. 1a. Therefore the size of the plotted area is directly dependent upon the number of section planes, and the difference between this area and that of the surface of the sphere will diminish as the number of section planes increases. This difference is that which is referred to intersectional curvature. There is, however, an error in this method which is entirely independent of the number of section planes. This may be demonstrated as follows:

Any two parallel section planes through the sphere, at the fraction of a radius apart, include between their peripheries (or line of intersection) an area, which is approximately equal to the product of a chord of the arc of a great circle, included at right angles between these peripheries, by half the sum of their lengths. The plotted area between these sections is, however, equal to half the sum of the peripheries by the distance of the sections apart. That is, if Δx equals the distance of the sections apart when the distance is appreciable and Δs equals the length of the corresponding chord, these areas, when referred to axes passing through the center of the sphere, will be:

$$(1.)\quad A=\Delta s\cdot\frac{2\pi y+2\pi(y+\Delta y)}{2}=2\pi\cdot\tfrac{1}{2}\left\{y+(y+\Delta y)^{*}\right\}\cdot\Delta s$$

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*dy is an infinitely small quantity, therefore, y+dy=y.

(2.) $B = \Delta x \cdot \frac{2\pi y + 2\pi(y + \Delta y)}{2} = 2\pi \cdot \frac{1}{2} \left\{ y + (y + \Delta y) \right\} \cdot \Delta x$

where A represents the actual surface area included between the sections, and B, the corresponding area obtained by plotting.

Passing to the limit, Δs becomes ds (differential s) and Δx becomes dx (differential x) and the equations 1 and 2 become

(3.) $A = 2\pi\ yds.$

(4.) $B = 2\pi\ ydx.$

Integrating these terms between the limits + r and — r, where r equals the radius of the sphere, we have:

(5.) $A = 2\pi \int_{-r}^{+r} yds$

(6.) $B = 2\pi \int_{-r}^{+r} ydx$

$2\pi \int_{-r}^{+r} yds$ is the expression for the surface area of a sphere which is equivalent to $2\pi\ (2\,r)^2 = 4\pi r^2$, therefore

(7.) $A = 2\pi \int_{-r}^{+r} yds = 4\pi\, r^2$

in equation $\int_{-r}^{+r} ydx$ is the expression for the area of a semi-circle which is equivalent to $\frac{\pi r^2}{2}$ therefore

8. $B = 2\pi \int_{-r}^{+r} yds = 2\pi \cdot \frac{\pi r^2}{2} = \pi^2 r^2$

and the relation between B and A may be expressed by the following proportion:

$B : A :: \pi^2 r^2 : 4\pi r^2$

$\frac{B}{A} = \frac{\pi^2 r^2}{4\pi r^2} = \frac{\pi}{4} = \frac{3.1416}{4}$ that is, the area obtained by the proposed method of plotting is, in the case of a sphere, $\frac{3.1416}{4}$ of the true surface area of the sphere.

Take next the case of a truncated cone, a section through the axis of which is represented by Fig. 2. Pass planes through the cone perpendicular to the axis at points A and B and at a distance x apart. By developing the peripheries of the sections through A and B into straight lines, as in the preceding example, and connecting the extremities of the lines, the figure A′ B′ B″ A″ is obtained. The periphery of a similar section of the cone formed by a plane through C, midway between, and parallel to the planes through A and B, is equal to half the sum of the peripheries of the sections through these two points ; so that it may be concluded that the area obtained by developing the peripheries of sections through a cone by this method is independent of the number and proximity of the section planes. In Fig. 2a

$$A' B' B'' A'' = x \cdot \tfrac{1}{2} (A' A'' + B' B'')$$

The area of the surface of the cone, however, between these two sections is

$$(x \cdot \text{secant } \alpha) \tfrac{1}{2} (A' A'' + B' B'')$$

where x equals the angle which the slant height of the cone makes with the axis, therefore:

surface area of cone : A′ B′ B″ A″ :: x sec. α : x : : sec. α : 1.

The difference between these two areas increases as secant α or angle α increases. When α is zero the cone becomes a cylinder, and the difference between the two areas zero. When $\alpha = 90°$, the cone becomes a plane of infinite extent and area. In this latter case the plotted area would be zero, and the difference at a maximum.

Take finally the case of a trough with a triangular section, as is shown by Fig. 3. Here, as in the case just considered, the area obtained by developing parallel sections will not be changed by the number and proximity of the section planes. If x represents the distance of the parallel planes a b c, a′ b′ c′, apart, the area obtained by developing, by the proposed method, one side of the trough between the lines as a′a′ and c′c′ would be $= x \cdot \tfrac{1}{2}$ (a c + a′ c′). The actual area of a a′ c c′ would be $= \tfrac{1}{2}$ (a c + a′ c′) times the perpendicular distance between the lines ac and a′c′. If the angle which the side of the trough makes with the plane of the section be represented by θ, this latter equation would be $= \tfrac{1}{2}$ (a c +

a′ c′) .x cosecant θ. If we draw a vertical line P c in the section a b c, and call the angle (P c o), which this line makes with o c, α, and the angle (P c a) which it makes with a c β, then

$$\tan \alpha = \frac{PO}{PC}, \text{ and } \sin \beta = \frac{PQ}{PC}$$

$$\text{therefore } \frac{\tan \alpha}{\sin \beta} = \frac{\left(\frac{PO}{PC}\right)}{\left(\frac{PQ}{PC}\right)} = \frac{PO}{PQ}.$$

$$\tan \theta = \frac{PO}{PQ}$$

$$\text{therefore } \tan \theta = \frac{\tan \alpha}{\sin \beta}$$

We have the general formula,

$$\text{cosecant } \theta = \sqrt{1 + \frac{1}{\tan^2 \theta}}$$

By substituting the value of tan θ in this equation

$$\text{cosec } \theta = \sqrt{1 + \frac{1}{\left(\frac{\tan^2 \alpha}{\sin^2 \beta}\right)}} = \sqrt{1 + \frac{\sin^2 \beta}{\tan^2 \alpha}}$$

therefore A (actual are aaa′ cc′)$=\frac{1}{2}$ (ac a′c′). x. $\sqrt{1+\frac{\sin^2 \beta}{\tan^2 \alpha}}$

and the relation between this area, and that which would be obtained by plotting, would be expressed by the following proportion, where B represents the latter area:

$$A : B :: \tfrac{1}{2} (ac + a'c').\ x.\ \sqrt{1+\frac{\sin^2 \beta}{\tan^2 \alpha}} : \tfrac{1}{2} (ac + a'c') ::$$

$$\sqrt{1+\frac{\sin^2 \beta}{\tan^2 \alpha}} : 1$$

Since the sine and tangent of an angle increase and diminish with the angle, it follows that the value of $\sqrt{1+\frac{\sin^2 \beta}{\tan^2 \alpha}}$ increases when β increases and diminishes when α increases;

in other words the plotted area approaches the true area directly as angle β diminishes and angle α increases.

Of the three theoretical cases which have been discussed, the results deduced from the last—that of a trough of angular section—are most generally applicable to the anthracite coal basins. The portion of the Panther Creek basin which was used in a former case, for the determination of the error due to intersectional irregularities, consists, in the main, of three troughs, which have approximately angular sections. If the lowest point in each of the 1,600′ sections of one of these troughs be connected with the two points of outcrop, and this figure be considered to represent the true section, and the sides of the trough between the sections be considered as planes, then the distance, 1,600′, of two successive sections apart, divided by the difference of altitude of the centers of the trough in the two sections, will be the tangent of the angle corresponding to α in Fig. 3; and the perpendicular distance of the outcrop of each side, from a vertical passing through the above-mentioned center of the trough, divided by the slant distance of this point of outcrop from the center, will be the sine of the angle corresponding to β in Fig. 3. Half the sum of the lengths of two successive sections, multiplied by their distance apart, will be equal to the area as plotted, while, as previously demonstrated, the true area will be this product multiplied by $\sqrt{1 + \frac{\sin^2 \beta}{\tan^2 \alpha}}$. Sin β and tan α are found as above described, and thus the difference between the plotted area and the true one, or the amount of the error in question, may be determined.*

* The area calculated on the assumption that the basin is made up of a series of *angular* troughs will evidently differ quite largely from the actual area, but the *relation* between the calculated areas and the true areas will be very nearly the same, whether a trough of angular section, or one of the true curved sections be considered, as the factors upon which this relation depends are appreciably the same in both cases. The error in assuming the basins as regular between the sections has already been determined and will alter the result by $\frac{2}{3}$ of 1 %. Another error is also introduced here, from the fact that in the intersectional trough the vertical plane which contains the inclined axis and which corresponds to M N O in Fig. 3, is not always perpendicular to the plane of the section, and, therefore, α is not always the angle which it is as-

Applying then this test to the eastern end of Panther Creek basin; in the case of the trough on the north side:

True area = 38,625,120 square feet.
Plotted area = 38,560,000 " "

In the middle trough:

True area = 8,928,000 square feet.
Plotted " = 8,915,200 " "

In the southern trough:

True area = 15,112,960 square feet.
Plotted " = 15,054,400 " "

The sum of these areas respectively is:

Total true area = 62,666,080 square feet.
" plotted " = 62,529,600 " "

Difference = 136,480
= .217% of total area.

$\frac{22}{100}$ of one per cent. is, then, the error due to the last discussed cause in the most eastern 18,000′ of the Panther Creek basin, and, as this may be considered a typical basin, it is allowable to conclude that the percentage of error will in general, not exceed this amount, and the total error from this cause in the estimate of the total Anthracite area will, be in the neighborhood of 1 square mile.* This error is fully within the limits of other unavoidable errors and it would, therefore, not be justifiable to expend a large amount of time in correcting it.

It was previously shown that the error due to intersectional irregularities was .688%; adding this to the last determined error of .217% gives a total error, due to the *method* of estimation, of .905%, or about 1.0% of the total area. Thus, in the estimate, by this method, of the total area of the Anthracite beds there would be an error of some 4 square miles.

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sumed to be in the correcting formula. This error will, however, certainly be inappreciable since the deviation of these planes from a perpendicular position to the sections is very slight in the basins in question, and a considerable deviation from that position would only make a very slight change in the angle α.

* It is to be noted here that, as the error is so small, the inaccuracies spoken of in the method of determining it, would be altogether inappreciable.

4. *Development of the Areas of the Coal Beds in the Panther Creek Basin* (*Miscellaneous sheet No. I*)

In the case of the eastern end of the Panther Creek basin, the horizontal trace of the vertical plane, on either side of which the cross section lines were developed into straight lines, is shown in the development contained on Miscellaneous sheet No. I, by a line running in the direction of the basin, from the lower end of section 1–1, to a point on section 21–21, between the developed contour lines – 200′ and – 400′. The magnetic bearing of this plane is S. 76° 3″ W.

The horizontal trace of the vertical plane, on either side of which the cross section lines, showing the floor of the Mammoth coal bed in the western end of the basin, were developed into straight lines, is shown by a line running in the direction of the basin from a point on *Section* No. 7,* between the developed positions of contour lines 400′ and 600′, on the northern side of the Coaldale anticlinal, and a point on *Section* No. 12, between the developed positions of contour lines –600′ and –800′, on the southern side of the Lansford basin.

The magnetic bearing of this vertical plane is S. 69° 47′ W., and the distance apart of the two vertical planes, that of the eastern end and that of the western end, along the horizontal trace of section plane 21–21 is 1460′.

The line of section, showing the floor of the Mammoth coal bed between these two planes along section 21–21, was developed into a straight line south from the eastern plane. On account of the sharp foldings of the beds between these two vertical planes at this point, the developed position of the point, where the Mammoth bed intersects the western plane, as developed south from the eastern plane, is shown on section 21–21, at a point between the developed position of the contour lines at tide level, and at –200′ on the southern side of the Bull Run basin.

The position of the horizontal trace of the western plane, which was used in laying off the developed sections, is

* On the sheet this horizontal trace should have been continued to section line 21–21.

shown by the straight line drawn from the point just described, to a point on section 37–37, midway between the developed positions of the contour lines –400′ and –400′ on either side of the Bull Run basin at Tamaqua. This line, as may be observed, is not parallel to the actual position of the horizontal trace. Its position as drawn was determined graphically, in order to diminish the error in developing the wedge shaped area between sections 21–21 and 22–22. The real difference between the surface underlaid by the Mammoth coal bed in the Panther Creek basin, and the surface area of the coal bed, is shown graphically on the sheet by the area included between the heavy black line, marked "Undeveloped Outcrop of the Mammoth Bed," and the line limiting the developed area, marked "Developed Outcrop of the Mammoth Bed."

The contents of these two areas were measured by Mr. Arthur Winslow, with Amsler's planimeter, in square inches of map surface, which were afterwards reduced to acres and square miles of actual area. In order to eliminate as far as possible all instrumental errors, and to prevent mistakes of record, three distinct measurements were made, with the planimeter, of every area. In the case of the Mammoth (E) bed, both the surface and bed areas have been classified into two distinct tables, the first including those areas contained between the planes of the twelve cross sections, (see Cross section sheets Nos. I, II, III,) and the second, those areas, embraced on the separate Mine sheets Nos. I, II, and III; so that 6 distinct planimeter measurements were made of the Mammoth bed areas.

The following tables give, respectively, the surface areas underlaid by the Mammoth (E), Buck Mountain, F or Lower Red Ash, and G or Upper Red Ash beds, and the developed surface areas of the coal beds, in acres and square miles:

Table I. Mammoth (E) Coal Bed. Inter-Sectional Areas.

	Surface Area Underlaid by Coal Bed.		Developed Area of Coal Bed. (Overturned and Regular Dips.)		Developed Area of Coal Bed having Regular Dips.		Developed Area of Coal Bed having Overturned Dips.		Area of Surface within Panther Creek Basin where Coal Bed has been Eroded.	
	Acres.	Sq. Miles.	Acres.	Sq. Miles.	Acres.	Sq. Miles.	Acres.	Sq. Miles.	Acres.	Sq. Miles.
Area bet. East end of Basin and Sec. No. 1,	3.23	.005	7 05	.011	7.05	.011				
" Section No. 1 and Section No. 2,	410.65	.642	706.56	1.104	687 02	1.073	19.54	.031		
" " 2 " " 3,	106.67	.167	196.29	.307	178.22	.279	18 07	.028	1.32	.002
" " 3 " " 4,	141.34	.221	237.72	.371	228.61	.357	9.11	.014	2.06	.003
" " 4 " " 5,	352.32	.551	560.66	.876	560.66	.876				
" " 5 " " 6,	1,131.46	1.768	1,728.41	2.701	1,728.41	2.701				
" " 6 " " 7,	598.57	.935	948.98	1.483	925 33	1.446	23.65	.037		
" " 7 " " 8,	444 30	.694	689 81	1.078	636.77	.995	53.04	.083		
" " 8 " " 9,	1,025.38	1.602	1,588.98	2.483	1,555 48	2.431	33.50	.052	.29	.0005
" " 9 " " 10,	796 92	1.245	1,291.76	2.018	1,291.76	2 018	. . . . . .	. . . . .	.29	.0005
" " 10 " " 11,	799.71	1.249	1,244.15	1.944	1,244.15	1.944				
" " 11 " " 12,	990.12	1.547	1,561.89	2.440	1,561.80	2 440				
" " 12 { Little Schuylkill River, }	52.16	.082	111.66	.174	111.66	.174				
Total areas Panther Creek basin, ...	6,852.83	10,708	10,873 83	16.990	10,716.92	16 745	156.91	.245	3.96	.006

Table II. Mammoth (E) Coal Bed. Mine Sheet Areas.

Mine Sheet No. I, ...	494.55	.773	862.74	1.348	828.36	1.294	34.38	.054		
Mine Sheet No. II, ...	2,817.41	4 402	4 405 67	6.884	4,300.91	6.720	104.76	.164	3.38	.005
Mine Sheet No. III, ...	3,532.49	5.519	5,590.02	8.734	5,571.36	8.705	18.66	.029	.44	.001
Total areas Panther Creek basin, ...	6,844.45	10,694	10,858.43	16.966	10,700.63	16 719	157.80	.247	3.82	.006

The areas given in Tables Nos. I and II were measured independently of one another. The total areas, Panther Creek basin, in each table, should be identical. The differences which exist are instrumental; they are, however, so small that they prove the efficiency of the Planimeter for the measurement of map areas.

Table III. Buck Mountain Coal Bed. Mine Sheet Areas.

	Surface Area Underlaid by Coal Bed.		Developed Area of Coal Bed.	
	Acres.	Sq. Miles.	Acres.	Sq. Miles.
Mine Sheet No. I, ...	780.61	1.219	1,362.16	2.128
Mine Sheet No. II, ...	3,321.95	5.191	5,195.53	8.118
Mine Sheet No. III, ...	3,925.52	6.134	6,210.17	9.703
Total areas Panther Creek basin, .	8,028.08	12.544	12,767.86	19.949

The areas given in Table III may be taken to represent the total surface area of the Panther Creek basin underlaid by *merchantable coal.* If the Lykens Valley coal beds, which have been opened in the Locust Mountain Gap, north of Tamaqua, (see cross section No. 12,) shall prove to be workable, this area will be very much augmented.

Table IV. F or Lower Red Ash Coal Bed. Mine Sheet Areas.

	Surface Area Underlaid by Coal Bed.		Developed Area of Coal Bed.	
	Acres.	Sq. Miles.	Acres.	Sq. Miles.
Mine Sheet No. I, ...	313.84	.490	549.22	.858
Mine Sheet No. II, ...	2,287.82	3.575	3,568.99	5.577
Mine Sheet No. III, ...	3,039.49	4.749	4,802.41	7.503
Total areas Panther Creek basin, .	5,641.15	8.814	8,920.62	13.938

The surface areas underlaid by the F bed were determined by interpolating the areas underlaid by the Mammoth (E) and G beds.

Table V. G or Upper Red Ash Coal Bed. Mine Sheet Areas.

	Surface Area Underlaid by Coal Bed.		Developed Area of Coal Bed.	
	Acres.	Sq. Miles.	Acres.	Sq. Miles.
Mine Sheet No. I, ...	59.14	.092	103.49	.162
Mine Sheet No. II, ...	1,543.68	2.412	2,408.14	3.763
Mine Sheet No. III, ...	2,346.82	3.667	3,707.98	5.793
Total areas Panther Creek basin, .	3,949.64	6.171	6,219.61	9.718

The surface areas underlaid by the G bed are approximate, and were determined by a location of all known outcrops, and from points obtained from the vertical cross-sections, (sheets I, II, and III.) The developed area of the coal bed was ascertained by proportion, based upon the relation of the surface area, underlaid by the Mammoth (E) bed, to the constructed developed area of the bed itself.

The tables are similar to those published on Miscellaneous sheet No. I. The facts which they contain are the basis for all the computations, which have been made of the coal contents of the Panther Creek basin, and which have been classified in the tables to follow.

Chapter VI.

1. Introduction; 2. Surface areas underlaid by the Coal Beds of the Panther Creek Valley; 3. The actual area of the surface of the Coal Beds in the Panther Creek Valley; 4. The actual surface areas of the Coal Beds where exploited at each Colliery; 5. Average thicknesses of the Panther Creek Coal Beds; Tables, I to XXXIV inclusive, showing the Tons of Commercial Coal originally contained in the Panther Creek Valley and the Tons which still remain; the Tons taken out at each Colliery and the Tons left in supports, with other facts connected with the methods and economy of Mining in the Panther Creek Valley.

1. Introduction.

The most important practical questions, which it seems desirable that the Geological Survey of the Anthracite Coal Fields should consider, are:

1st. How much coal was originally contained in any special geographical area.

2d. How much coal was originally contained in that part of the above area which is under exploitation.

3d. The amount of coal which has been taken out of the area which is under exploitation.

4th. The amount of coal which still remains in the exploited part, and

5th. How much, of this coal which remains, can still be won, by more careful working in carrying out the mining system, which is in present use; or by the employment of a better and more economical method of mining.

The original plan which I outlined for the Survey did not provide for the consideration of these questions, except in a very general way. It was thought that sufficient facts could not be obtained, upon which to base any estimates which would be of permanent practical value. I had hoped that, after the completion of the entire Survey, it might be possible to state in a general way, for the prominent geographical and geological sub-divisions of the coal-fields, (a) the amount of coal which had been taken out up to a given date, and (b) that which *probably* still remained. Such a result would have been of limited practical value ; it would only have proved important, as indicating the possibilities for future mining, in these sub-divisions, and their probable ultimate exhaustion.

With this end in view, special examinations were made of all the mines in the Panther Creek basin, after the mapping and purely geological work of the district had been completed. In order to obtain the most accurate results in the consideration of these two questions (a and b), special parts of each mine, in which any independent data could be procured, were separately studied ; not, however, with the intention of publishing the results obtained in the individual parts, but to enable me to prove the ultimate result, by a comparison of the similar factors used in the different parts of each mine, by means of which it could be decided, whether the average measurement or estimate had been obtained in each case. The estimates used and the results of this investigation were carefully tabulated, in detail. Many important conclusions were arrived at, not only connected with the consideration of the two questions involved, but which threw considerable light upon the economy of mining and the adaptation of different methods of working to coal beds of varying thickness, to varying alternations of rock, coal, and slate in the bed, and to the different attitudes in which the beds were found.

A consultation was had with Mr. Joseph S. Harris, President, and Mr. Wm. D. Zehner, Superintendent of the Lehigh Coal and Navigation Company, upon whose property this investigation was made. Both of these gentlemen have for a number of years been directly connected with the mining of anthracite, under probably as many varying conditions as any engineers in the anthracite region. The detailed results, obtained in the different parts of the mines, were considered by them to be of great practical importance, and it seems desirable they should be published in full. As it was not my original intention that this should be done, I was not satisfied that the Survey should be committed to such detailed results, unless a more careful, thorough, and personal examination of the mines should be made, by the Survey, than that which had already been accomplished. To do this, however, without very materially retarding the general work of the Survey, would involve an increase in the field corps, and a consequent expense far beyond the limits of the appropriation. It was impossible to increase the corps to provide for this work, which, if undertaken in the Panther Creek basin and proved of practical value, should be prosecuted throughout the entire field; in consequence the work which was being carried on under the original plan, already approved by the State Geologist and Board of Commissioners, would have to be temporarily suspended in special parts of the field to permit of this work being done.

The preliminary tables already constructed were referred to Professor Lesley, and Mr. Wm. A. Ingham, Secretary of the Board, with the result of my interview with Messrs. Harris and Zehner. Their views were confirmed and I was instructed to make the investigation sufficiently thorough, to enable the Survey to publish tables which should answer, not only the two questions (a and b) originally considered, but the five outlined above.

Before carrying these instructions into execution, others having interests in the anthracite coal-fields were consulted as to this special work. Although it was found that the investigation, which should be prosecuted with a view of answering the two questions (a and b) of wider scope, would be concurred in, many questioned, as I had already done myelf, whether it would be possible to make mine examinations, as thorough as it was proposed to do in the Panther Creek basin; and if such results, if published with equal minuteness in all the coal basins, would be of practical value. In many cases, however, I found that such doubts, arose more from an unfamiliarity with the plan proposed and the results to be attained than from any condemnation of the method. In every case, it seemed to be admitted that the experiment was worthy of a trial, and that, if the estimates could be depended upon, as being as reliable as those of the Panther Creek basin, the results of such an investigation would constitute one of the most important features of the Anthracite Survey.

Undertaking this work for the entire anthracite region, as it is now proposed to do, will very seriously retard the progress of the Survey, and will prove one of the many elements, some of which have already been considered, others which cannot be anticipated, which render it impossible to make any estimate, as to the time of the ultimate completion of the Survey of the anthracite fields. It is now generally considered, both by the management of the Survey and those who are directly interested in the work, that the only practical policy to pursue, in making the survey of this region, is to accomplish as much as possible within a given time, without detracting from the practical value of the work, irrespective of how long it will take to complete it.

If the State Legislature shall discontinue the appropriations for this Survey, at any time before it shall be finished, practical results will have been attained in the area examined, and the boundaries of the areas yet untouched will be clearly defined.

The method which I have proposed for obtaining the contents of highly plicated coal beds, the practical application of which has already been explained (see Chapter V), was originally designed for answering the general questions (a and b) as to the amount of coal taken out and that still remaining; but it is equally applicable to the more detailed investigation referred to.

In special areas it may be necessary to apply this method, independently and in detail, to several coal beds rather than to one, as in the case of the Panther Creek valley, where the Mammoth bed (E or Top Split) was specially considered. In this basin, the peculiarities of the structure and the position and character of the exploited area were such, that I have considered it quite sufficient, to develop the area of the Mammoth bed alone and to apply to the other beds, both above and below the Mammoth, the constants showing the relationship of the surface area underlaid by the Mammoth bed to the area of the bed, in any unit of surface area. As has already been explained in Chapter V, to practically apply this method for obtaining the contents of a coal bed under any special area, it is necessary to obtain the surface area underlaid by the coal bed, the area of the surface of the bed itself, and the average thickness of coal contained in the bed, which, if mined out, can be marketed for fuel. The sudden changes in thickness to which a coal bed is found to be subject, and the difficulty of assigning an average thickness to any one bed over any considerable area, make it necessary, to divide the exploited areas in each mine, or the unmined areas throughout the district, in such a way, that it may be quite possible to consider, that each division is underlaid throughout by a bed containing an equal thickness of coal.

The difficulty, which is so frequently experienced, in deciding upon the value to be attached to such estimates, in consequence of not understanding the details of the method used or the exact factors employed, makes it particularly desirable, that in the Survey estimates no pains should be spared to explain the methods employed and all the principles involved, and to state the facts and estimates used in obtaining the final results, so that any engineer or geologist, who may have occasion to make use of the conclusions of such an investigation, shall be able to test their accuracy, and to judge of the absolute practical value to be attached to them.*

While this plan may be desired, by those who may wish to make use of the results, I realize, at the same time, that the Survey may thus furnish means of condemning its own

* In the tables the results are stated to the single ton. For practical purposes, it might have been sufficient to have stated the results in units of millions, thousands or hundreds. It was thought best, to state the exact results of the computations, since all the factors which enter into them are given and the results can in consequence be more readily varified, or modified, by a change of any one individual factor which may be deemed desirable.

work. It is my belief that, in private professional work, where the results of one's work depend largely or solely upon the individual experience and judgment of the investigator, that he is justified in stating his results without giving the facts or the line of argument. Such work, however, cannot be accepted, with implicit confidence, unless the value of the experience and judgment of the investigator is known. In the case of a public survey, I believe that all the facts which are used in any investigation should be clearly stated, so that from a personal examination of the subject by an expert, the results can be accepted with confidence or can be rejected with reason.

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2. Surface areas underlaid by the Coal Beds of the Panther Creek Valley.

The factors which have been used in computing the following tables, and the method of obtaining them will now be described.

The surface areas in the Panther Creek basin which are underlaid by the individual coal beds were obtained as follows, in the order of their superposition, commencing at the top of the section and descending to the bottom.*

The outcrops of the Third and Second Upper Red Ash beds were outlined on the original of the mine sheets (scale 400′=1″) from surface points determined along the line of each cross-section, intersected by the beds, and between the cross-sections by tracing the outcrops on the map in their relation to that of the G bed. The enclosed area was measured by the planimeter in square inches of map area, which were afterwards converted into acres of ground measure.†

The area underlaid by the First Upper Red Ash bed was

*See columnar section on Mine sheet No. III, and columnar section No. 17, Columnar section sheet No. II.

† In all cases where the planimeter was used for measuring map areas, two and sometimes three distinct and independent measurements were made. Although it was found, that no material difference existed between the different measurements, yet the precaution was always taken to prevent any possible instrumental or personal error.

obtained by taking the mean between the area of the Second Upper Red Ash bed and that of the Second Twin beds.

The outcrops of the Second Twin beds were located similarly to those of the Third and Second Upper Red Ash beds.

In the case of the First Twin beds the surface area underlaid by coal on Mine sheet No. II was obtained in the same way; on Mine sheet No. III it was determined by taking a mean between the area, underlaid by the Second Twin beds and the Jock bed.

The area underlaid by the Jock bed on Mine sheet No. II was ascertained, by taking the mean between the areas underlaid by the Washington bed and the First Twin beds; on Mine sheet No. III it was determined by an independent measurement as above.

A similar independent measurement was made for the area underlaid by the Washington bed on Mine sheet No. II; on Mine sheet No. III it was obtained by taking the mean of the areas underlaid by the G and Jock beds.

None of the above coal beds outcrop on Mine sheet No. I; the following beds, however, are found to outcrop within the area embraced by each one of the three mine sheets.

The outcrop of the G bed was independently located on the original of the mine sheets, and the included area measured as above.

The area underlaid by the F bed was obtained by interpolating similar areas for the E and G beds.*

The surface underlaid by the Five-Foot bed on Mine sheet No. I, where, as far as we are at present, able to judge, will alone be found of workable dimensions, was obtained by interpolating similar areas for the E and F beds on this same sheet.

The outcrop of the Mammoth bed† was independently outlined on the mine sheets, and its area measured.

The area underlaid by the C bed was obtained by taking

*The Second Red Ash bed, sometimes known as the Bony bed, which is found best developed at Tunnel No. 11, is not considered in computing the total orignal contents of the Panther Creek basin, as its extent is not certainly known.

† The Mammoth bed here includes the E, Cross-cut, and D beds.

a mean between the areas underlaid by the B and Mammoth beds.

The outcrop of the B bed was independently located and its area measured.

On account of the uncertainty of the position of the outcrop of the A bed, the surface which it was considered to underlie has been considered to be the same as that of the B bed.*

The areas of the surface at each colliery, under which a bed has been worked, were obtained by carefully outlining these areas on the large mine maps (scale 100′=1″) of the Lehigh Coal and Navigation Co. In this work the Survey corps was assisted by Mr. John C. Rutter, mining engineer, whose long connection with the mine surveys in the Panther Creek valley has rendered him thoroughly familiar with the extent of all the mine workings.

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3. *The actual area of the surface of the Coal Beds in the Panther Creek Valley.*

The actual area of the surface of the anthracite coal beds under any given tract is greater than the surface area of the tract, since there is no body of land in the Anthracite Coal Fields underlaid by coal beds, where the surface of any one bed is horizontal over any considerable area. If such were ever the case, the estimate of the coal contents would be comparatively simple. On account of the great flexuring which has taken place in the anthracite region all the coal beds lie at angles, varying from a horizontal dip over small areas to a vertical and even overturned dip.

Any area can be underlaid by a varying amount of coal, between the extreme cases where the bed is horizontal and its area equivalent to that of the tract, to a case where the bed is perpendicular, and its area dependent only upon the depth of the basin.

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*In every case where different values might be attached, with reason, to the various factors used in computing the tables, the minimum value was always taken.

The method by which the area of the surface of the floor of the Mammoth bed was obtained has already been explained in detail in Chapter V. The areas of the coal beds, lying above the Mammoth and the area of the B bed lying below it, have been obtained, by assuming that the relation, existing between the surface area underlaid by the Mammoth and the area of the surface of the Mammoth, is the same, as it is in these coal beds.

The bed areas in each 500 foot vertical zone, as classified in table No. 1, were calculated from measurements made on each of the three mine sheets. The distance along the floor of that portion of a bed, included within each zone, was cut by equi-distant section planes across the basin. The average length of the developed section lines was then multiplied by the mean length of the bed, along its strike, in each zone respectively for the area of the surface of the bed within the zone.

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4. The actual surface areas of the Coal Beds where exploited at each Colliery.

The surface areas, of that portion of the coal beds under exploitation at each colliery, were determined, by developing into a horizontal plane (as in the case of the entire surface of the Mammoth bed already explained) the surface area of the coal beds in the exploited areas. This would apply, especially, to those areas where the surface of the coal-bed is considerably contorted by flexures.

The areas of the coal beds, under the smaller surface areas, where the dip of the beds is approximately the same throughout, were obtained directly by calculation without going through the more tedious method of a geometrical development. After the surface areas were measured, the areas of the surface of the coal-beds were determined, by dividing the former areas by the cosine of the angle of dip.

As will be observed, from an inspection of the tables, estimates have been made, in most cases, between the main gangways driven at different levels at each colliery. This has been done, more particularly, in cases where the bed has been mined on comparatively steep dips, and where the coal has been taken from breasts worked from a lower gangway, which has been driven nearly level along the strike of the bed, 300′ from an upper gangway; the measurement being made along the dip of the bed. It was necessary, in such cases, to determine the areas of the beds between these different gangways; this was done by measuring the distance apart of the gangways on the dip, along equi-distant cross-sections at right angles to the strike of the bed. From these measurements, the average distance of the gangways apart was obtained, which being multiplied by the length of the area under discussion, gave the actual area of the surface of the coal bed between the different gangways. In all these estimates duplicate computations were made, independent of one another, for the prevention of error.

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5. *Average Thicknesses of the Panther Creek Coal Beds.*

The plan pursued in obtaining the average thickness of commercial coal contained in any bed in these areas was determined as follows: All the bed sections in the possession of the Lehigh Coal and Navigation Co. and those made by the Geological Survey, were first tabulated.* Information was then sought from every one who had had personal connection with the past mining at each colliery, or parts of collieries.†

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*The bed sections, on Columnar section sheet No. III, do not show the average thicknesses of the different coal beds, but rather the variations in structure and thickness which the beds undergo. At Colliery No. 9 the average thickness of the Mammoth bed is 50 feet with an average of 25 feet of coal, although at one point in the mine the bed has an abnormal thickness of 114 feet with 105 feet of coal.

† It is impossible to enumerate all the sources from which such information was obtained. The principal persons consulted, however, were the following: Of the Lehigh Coal and Navigation Company, Joseph S. Harris, President; Wm. D. Zehner, Superintendent; John C. Rutter, Mining Engineer; Wm. Evans, Inside Superintendent Panther Creek mines, and Richard Eustis, Inside Superintendent Nesquehoning mines. Wm. A. Ingham, formerly President of the Greenwood Coal Company; Robert Carter, Roland Jones and John Wentzel, formerly Superintendents of all or portion of the mine workings of the Greenwood colliery; Richard Curnew, miner, formerly employed at Greenwood; Mr. Mitchell, of Mitchell and Symonds, who are now mining the C bed at Tamaqua; inside foreman at each colliery, miners, and others.

The mine workings at each colliery were afterwards examined, in company with those directly superintending the mining of the coal, and estimates made, as to the average thickness of the coal beds in different parts of the mine and the average thickness of coal contained in the bed. This distinction of coal bed and coal, or that which if taken out of the mine can be marketed for fuel, is very important on account of the varying amount of rock, slate, bony coal and *bad stuff* which the different beds contain. A glance over these estimates, in table No. I and the colliery tables, will show how variable the proportion of good coal in different beds is, or in fact in the same bed in different areas. This feature has already been referred to in the description of the coal beds (see Chapter IV.)

In addition to these estimates, facts were obtained in the mines, which combined with results of surveys and information already recorded, permitted of very close estimates being made, as to the percentage of the coal originally contained, that which had been taken out of the different parts of the mines, and the percentage of the whole which still remained. Of this latter amount, estimates were made as to what additional percentages could be robbed from the unfinished breast, the chain pillars, and the gangway pillars at present standing, without either endangering the safety of the miners or injuring the value of the property for future mining in overlying beds.

The average specific gravity of the Panther Creek coals is taken as 1.6307; or 101.64 avoirdupois pounds to 1 cubic foot; 22.038 cubic feet in one ton of 2240 pounds, and 1976.586 tons to one acre of coal one foot thick.* In computing the tonnages in the tables, 1975 tons to the foot acre have been used. (See Table No. 1, Chap. VII.)

The following tables contain the coal estimates which have been made in the Panther Creek basin between Tamaqua and Mauch Chunk, in order to answer the five questions proposed on page 126, as follows:

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*This is the amount of coal actually contained. For the percentage of this which has been mined out the reader is referred to table No. XXXIV.

Tables I and II give the amount of commercial coal in tons, originally contained in the Panther Creek basin.

Tables III to XXVIII, inclusive, give the original contents of the area at each colliery which was under exploitation, or that which was opened up and in which mining had been carried on up to January 1, 1883; the number of tons which had been taken out of this area up to the same date; the number of tons which still remained in this area; and the number of tons of that which remained, which could still be mined. In addition to these results, many facts and conclusions are stated, relative to the local condition of the different mines and the economy of the different methods of mining; these will be readily appreciated by those familiar with the mining of Pennsylvania anthracite, without further explanation. A general discussion of the subject will be delayed until the publication of the final report.

Tables XXIX and XXX contain a general summary of the results stated in detail in Tables III to XXVIII inclusive.

Table XXXI shows the total production of commercial coal in the Panther Creek Valley from the commencement of mining to January 1, 1883.

Tables XXXII and XXXIII contain records, carefully kept by the Lehigh Coal and Navigation Company, of the distribution of all the coal which was taken out of their Panther Creek mines for 2 years from January 1, 1881, to January 1, 1883.

Table XXXIV shows the percentage of the commercial coal which was originally contained in the exploited area, which has been produced and disposed of for fuel; that which has been wasted in the mines; and that which has been wasted on the dirt banks.

TABLE No. I*.—*Total amount of Commercial Coal originally contained in the Coal Beds of the Panther Creek Basin, divided into areas covered by Mine sheets Nos. I, II, and III; and vertical zones between outcrop and + 500 feet; + 500 feet and Tide Level; Tide Level and—500 feet; and below — 500 feet.*

Southern Coal Field, Mine Sheet No. I.

NAME OF BED.	Surface area (Acres)	BETWEEN OUTCROP & + 500′.				BETWEEN + 500′ & TIDE LEVEL.				BETWEEN TIDE LEVEL & — 500′.				BELOW — 500.				Total tons under area covered by Mine sheet No. I.
		Bed area (Acres).	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	
G, or Upper Red Ash,	59	103	5′	2½′	510,982	. .	. .	.	. . . .	. . .	. . .	. . .	. . . . . .	. . .	. . .	. . .	Lykens Valley beds are the only ones in this zone on this sheet.	510 982
F, or Red Ash,	314	549	13′	9′	9.762.385		.		. .	. . .	. .	. .	. . . . . .	. . .	. . .	. .		9 762.385
Five Foot,	404	647	4½′	3′	3 835,726	59	4½′	3′	347,205	. . .	. . .	. . .	. . . . . .	. . .	. . .	. . .		4,182,931
E, (Top Split,) "Cross Cut," (Middle Split,) D, (Bottom Split) } Mammoth.	495	746	29′	23′	33 866,154	117	29′	23′	5,323,810	. . .	. . .	. . .	. . . . .	. . .	. . .	. .		39,189,964
C,	638	785	4½′	3′	4,648 696	300	4½′	3′	1,778,329	28	4½′	3′	164.241	. .	. . .	. . .		6,591,266
B,	781	824	15′	10′	16,266,692	483	15′	10′	9,541,225	55	15′	10′	1,094.940	. .	. . .	. . .		26 902 857
A,	781	824	3′	1′	1,626,665	483	3′	1′	954,103	55	3′	1′	109,494	. . .	. . .	. . .		2,690,262
Lykens Valley.*																		
Totals,	. .	.	74′	51½′	70,517,300	.	56′	40′	17 944,672	.	22½′	14′	1,368 695	.		.	. . .	89 830,647

*The Lykens Valley beds are not considered in this table, as nothing is certainly known of their extent or thickness.

Table No. I—*Continued.*

Southern Coal Field, Mine sheet No. II.

Name of Bed.	Surface area (Acres.)	Between Outcrop & + 500′.				Between + 500 and Tide Level				Between Tide Level and − 500′.				Below − 500′.				Total tons under area covered by Mine sheet No. II.
		Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	
2nd Twin,	84	132	. . .	. . .	. . . . . .	. .	. .	. .	. . . . . .	. . .	. . .	. . .	. . . . . .	. . .	. . .	. . .	. . . . . .	. . . . . .
1st Twin,*	322	502				. .	. .	. .	. . . .	. . .	. . .	. . .	. . . . . .	. . .	. . .	. . .	. . . . . .	
Jock,	703	1096	7	3	6,495,400	.			. . .	. . .	. . .	. . .	. . . . . .	. . .	. . .	. . .	. . . . . .	6,495,400
Washington,	1083	1639	3′	1′	3,236,986	50	3′	1′	98,513	. . .	. . .	. . .	. . . .	. . .	. . .	. . .	. . . . . .	3,335,499
G, or Upper Red Ash,	1544	2091	6′	3′	12,389,175	317	6′	3′	1,878,225	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . . . . .	14,267,400
F, or Red Ash,	2288	2475	9′	5′	24,443,192	1036	9′	5′	10,232,080	58	9′	5′	568,504	. . .	. .	. .	. . . . . .	35,243,776
Five Foot,	. . .		. . .	.	. . . . .	. . .	. . .	. . .	. . . .	. . .	. .	. .	. . . . . .	. .	.	. .	. . . . . .	. . .
E (Top Split,) "Cross Cut," (Middle Split,) D (Bottom Split) } Mammoth.	2817	1888	55′	27′	100,679,200	1665	55′	27′	88,793,057	803	55′	27′	42,801,844	50	55′	27′	2,659,318	234,933,419
C,	3070	1906	5′	3′	11,293,939	1474	5′	3′	8,733,391	995	5′	3′	5,893,183	426	5′	3′	2,523,043	28,443,556
B,	3322	1924	8′	2′	7,600,866	1283	8′	2′	5,067,257	1187	8′	2′	4,687,189	802	8′	2′	3,167,031	20,522,343
A,	3322	1924	5′	2′	3,799,900	1283	5′	2′	2,533,925	1187	5′	2′	2,344,325	802	5′	2′	1,583,950	10,262,100
Totals,	. . .	.	98′	46′	169,938,658	. . .	91′	43′	117,336,448	.	82′	39′	56,295,045	. .	73′	34′	9,933,342	353,503,493

* Thicknesses of Coal Beds above the Jock Bed unknown (see pages 85 and 86.)

TABLE No. I—*Concluded.*

Southern Coal Field, Mine sheet No. III.

Name of Bed.	Surface area (Acres.)	Between Outcrop & + 500′.				Between + 500′ & Tide Level.				Between Tide Level & — 500.				Below — 500′				Total tons under area covered by Mine sheet No. III.	Total tons under area covered by Minesheets Nos. I, II and III.
		Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed.	Average thickness of coal.	Tons.	Bed area (Acres.)	Average thickness of bed	Average thickness of coal	Tons.		
3rd Upper Red Ash,	15	22	..	..	......	1	..	..	......	..	..	.	......	...	..	..	......	......	......
2nd Upper Red Ash,	39	51	..	..	......	11	..	..	......	...	..	..	......	...	..	..	......	......	......
1st Upper Red Ash,	189	190	..		......	109	..	..	......	..	..	..	......	...	..	..	......	......	......
2nd Twin,	339	401	..	..	......	134	.	..	......	2	..	..	......	...	..	..	......	......	......
1st Twin,*	792	722	.		...	481	.	..		48	..	..	..	...	..	..	......		......
Jock,	1245	929	7′	3′	5,505 214	929	7′	3′	5 505.214	109	7′	3′	647.662	...		.	......	11,658.090	18,153,490
Washington,	1796	1526	3′	1′	3 013,356	1282	3′	1′	2 531.219	31	3′	1′	60 257	.		.		5 604.832	8,940 331
G, or Upper Red Ash,	2347	1645	5′	3′	9.748 876	1410	5′	3′	8 356 205	646	5′	3′	3 829.920	6	5′	3′	34,780	21,969 781	36 748 163
F, or Red Ash,	3039	1727	12′	9′	30,697,425	1511	12′	9′	26,858,025	1241	12′	9′	22,058 775	324	12′	9′	5,759,100	85 373,325	130.379 486
Five Foot,	...	....	.	..	......	..		.	...	.	...	..	.	.	...	.	.	.	4,182.931
E (Top Split,) ''Cross Cut,'' (Middle Split,). D(Bottom Split) } Mammoth.	3532	1489	43′	27′	79,454,250	1503	43′	27′	80,147,475	1763	43′	27′	94,065,300	836	43′	27′	44 579,700	298,246,725	572,370,108
C,	3729	1501	11′	8′	23 708,216	1102	11′	8′	17,415 866	1341	11′	8′	21,180,216	1957	11′	8′	30 917,440	93 221.738	128,256.560
B,	3326	1512	6′	2′	5,972 400	702	6′	2′	2 772 900	918	6′	2′	3 626,100	3078	6′	2′	12.158 100	24,529,500	71.954,700
A,	3926	1512	7′	4′	11,944 800	702	7′	4′	5,545,800	918	7′	4′	7,252,200	3078	7′	4′	24 316,200	49,059,000	62,011 362
Totals,	...	...	94′	57′	170,044,537	.	94′	57′	149,132,704	...	94′	57′	152,720,430	.	84	53′	117,765,320	589,662,991	1,032,997,131

* Thicknesses of Coal Beds above the Jock Bed unknown (see pages 85 and 86.)

NOTES.—1. If the thicknesses of the coal contained in the beds above the Jock bed are estimated as follows: Second Upper Red Ash bed, 1′; First Upper Red Ash bed, 2′; Second Twin bed, 2′; First Twin bed, 2′; the aggregate amount of coal contained would be about 11,000,000 tons. The Third Upper Red Ash bed is not considered in this estimate. The total coal contained, given in the above table, does not include these 11,000,000 tons.

2. In the calculation of the tonnage, in the above table, the decimal parts of the acre to hundredths, obtained in the measurement of the areas, were used; whereas, in recording the areas in the table the decimal parts of the acre have been disregarded and the results given to the nearest uuit.

TABLE NO. II.—*Total amount of Commercial Coal originally contained in the Coal Beds of the Panther Creek Basin divided into vertical zones between outcrop and + 500 feet; + 500 feet and Tide Level; Tide Level and—500 feet; and below—500 feet.*

TONS.	3rd Upper Red Ash bed.	2nd Upper Red Ash bed.	1st Upper Red Ash bed.	2nd Twin beds.	1st Twin beds.	Jock bed.	Washington bed.	G, or ' Upper Red Ash bed.
Between outcrop and+500,	. . . .	. . . .	. . . .	. . . .	. . . .	12,000,614	6,250,342	22,649,033
Between+500' and Tide Level,	. . . .	. . . .	. . . .	. . . .	. . . .	5,505,214	2,629,732	10,234,430
Between Tide Level and—500',	. . . .	. . . .	. . . .	. . . .	. . . .	647,662	60,257	3,829,920
Below—500',	. . . .	. . . .	. . . .	. . . .	. . . .	. .	. . . .	34,780
	. . . .	. . . .	. . . .	. . . .	. . . .	18,153,490	8,940,331	36,748,163

TONS.	F, or Lower Red Ash bed.	Five Foot bed.	Mammoth bed. E. (top split.) Cross-cut (mid. split.) D. (bottom split.)	C bed.	B bed.	A bed.	Total tons under area covered by Mine sheets Nos. I, II and III.
Between outcrop and+500',	64,903,002	3,835,726	213,999,604	39,650,851	29,839,958	17,371,365	410,500,495
Between+500 and Tide Level,	37,090,105	347,205	174,264,342	27,927,586	17,381,382	9,033,828	284,413,824
Between Tide Level and—500',	22,627,279	. . . . .	136,867,144	27,237,640	9,408,229	9,706,019	210,384,150
Below—500',	5,759,100	. . . . .	47,239,018	33,440,483	15,325,131	25,900,150	127,698,662
	130,379,486	4,182,931	572,370,108	128,256,560	71,954,700	62,011,362	1,032,997,131

NOTE.—If the thicknesses of the coal contained in the beds above the G bed are estimated as follows: Second Upper Red Ash bed, 1'; First Upper Red Ash bed, 2': Second Twin bed, 2': First Twin bed, 2'; the aggregate amount of coal contained would be about 11,000,000 (exact result of computation 10,868,287) tons. The Third Upper Red Ash bed is not included in this estimate.

TABLE NO. III.—*Hacklebarney Tunnel (abandoned).*
Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined. Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	Percentage of coal which cannot be mined.
		Acrs.	*Acrs.*		*Feet.*	*Feet.*						
E, . . .	Hacklebarney Tunnel and Inside Slope. N. and S. dips, Hell Kitchen basin, ...	21.93	48.85	60°	30	24	50					
B, . . .	N. dip, Hell Kitchen basin, ...	5.69	9.94	60°	12	9	65					
	Total, ...						(51 average.)					

The Mammoth (E), Buck mountain (B), and "Five-Foot" bed have been mined at the Hacklebarney or Old Mauch Chunk tunnel. In the eastern end of the basin the Mammoth bed was mined in the center of the synclinal. No estimate has been made of the relative size of the area here, where the bed laid comparatively horizontal, with the areas west of the tunnel, where the Mammoth bed was worked on high dips. As a result 60° *may not be* an average dip of the bed over the entire area mined, as is stated in the above table. On Mine sheet No. I the gangway driven in the Buck Mountain bed from the tunnel, and the approximate outcrop of this bed on the south side of the basin, have not been correctly placed. As they are now placed, relative to one another, an overturned dip in the bed would be indicated, whereas it has a north dip to the face of the gangway. From 800 to 1000′ west of the tunnel the bed dips 45° north-west; 1500′ west it dips 55° and continues to steepen until it attains nearly a perpendicular dip at the face of the gangway.

TABLE NO. IV.—*Hacklebarney Tunnel (abandoned).*

Tons of Coal Originally Contained, Mined, and still to be Mined.

NAME OF BED.	DIVISION OF COLLIERY.	Total original coal contents.	Amount of coal taken out of mine.	AMOUNT OF COAL WHICH CAN STILL BE MINED.*				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
E, . . .	Hacklebarney Tunnel and Inside Slope. N. and S. dips, Hell Kitchen basin, ...	2,315,490	1,157,745					
B, . .	N. dip, Hell Kitchen basin, ...	176,683	114,844					
	Total, ...	2,492,173	1,272,589					

*In many cases it was impossible to obtain sufficient facts, to make an estimate of the number of tons which can still be mined. Blank spaces have, however, been left in the tables, in which the results of any estimates made in the future can be placed.

NOTE TO TABLES GIVING MINE MEASUREMENTS AND ESTIMATES.—By the *area under development*, in the tables, is meant the exploited area, or that which was opened up and in which mining had been carried on up to January 1st, 1883; this is the date up to which all the colliery estimates have been carried.

TABLE NO. V.—*Nesquehoning Colliery No. 3.*
Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined: Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	Per ct. of coal which cannot be mined.
		Acres.	Acres.		Ft.	Ft.						
G, (1.)	Drift, N. dip, Greenwood basin,	4 28	13.69	70°	7	5	75	. . .	. . .	. . .	. . .	25
" (2,)	Tunnel No. 1, S. dip, Greenwood basin,	1.10	1 17	55°	5	3	60					
F,	Tunnel No. 1, S. dip, Hell Kitchen basin,	30.13	41.32	45°	12	9	50					
"	" " overturned dip, Hell Kitchen basin,	15.64	21.90	50°	10	6	60					
" (3,)	Tunnels Nos. 1 and 2, Shaft No. 1, Slope No. 2, N. and S. dips, Greenwood basin,	45.62	90.32	60°	12	9	76	. . .	1	2	1	20
"	Tunnel No. 1, N. dip, Lansford basin No. 2,	3.61	5 42	50°	12	8	60					
"	Tunnels Nos. 1 and 2, N. dip, Lansford basin No. 1,	18 41	46.15	70°	17	12	60					
"	Tunnel No. 2, S. dip, Lansford basin No. 2,	5.43	8 64	60°	12	9	60	. . .	10	5	. . .	25
"	Slope No. 3, S. dip, Hell Kitchen basin,	23.74	32.36	48°	14	10	62	. . .	5	5	. .	28
5-Foot,	Tunnel No. 1, S. dip, Hell Kitchen basin,	9.21	13.82	50°	5	3	70					
"	" " overturned dip, Hell Kitchen basin,	.83	1.17	55°	5	2.5	30					
"	" " N. dip, Greenwood basin,	1 20	6.15	80°	4	3	50					
E,	Tunnel No. 1, Slope No. 1, S. dip, Hell Kitchen basin,	79.70	135 28	42°	20	16	45					
" (4,)	Tunnels Nos. 1 and 2, Shaft No. 1, Slope No. 4, N. and S. dips, shaft anticlinal,	18.50	62.38	70°	34	22	69	. . .	3½	10½	3½	13½
"	Tunnel No. 1, N. dip, Lansford basin No. 1,	12 27	16.95	77°	30	20	40					
"	Slope No. 3, S. dip, Hell Kitchen basin,	37 33	52.38	40°	20	16	62	10	4	4	. . .	20
	Total,						(58 average.)					

(1.) The bed area assigned to this drift was measured in length, the same as the gangway; and in height from the gangway level to the outcrop. I think it is doubtful whether 75 per cent. of the coal originally contained in this area has been actually removed, as has been estimated and stated in the table. (2.) This gangway has not been placed on the Mine sheet No. I. (3.) These gangways cross in the basin and in consequence of this fact, which is due to the peculiarities of the structure, it was impossible to separate the estimates. (4.) The coal which is still available in this division lies entirely on the north side of the shaft anticlinal. On the south side 90 per cent. of the original coal contents has been removed; the 10 per cent. that remains may be considered lost. The high percentage obtained here, was due to the fact that mining was carried on so near the anticlinal arch, that the roof rocks were self-sustaining. It is estimated that 25 per cent. of the original contents can still be removed from the workings on the north side of the anticlinal. This percentage, however, if distributed over the entire area of the division, as has been done in the table, would make only 17½ per cent. of the original contents available.

TABLE No. VI.—*Nesquehoning Colliery No. 3.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
G, (1,)	Drift, N. dip, Greenwood basin,	135,189	101 392	.....	.....	.....	.....	33,797
" (2,)	Tunnel No. 1, S. dip, Greenwood basin,	6.932	4 159					
F,	Tunnel No. 1, S. dip, Hell Kitchen basin,	731 463	367 232					
"	" " overturned dip, Hell Kitchen basin,	259,515	155,709					
" (3,)	Tunnels Nos. 1 and 2, Shaft No. 1, Slope No. 2, N. and S. dips, Greenwood basin,	1,605 433	1,220 133	......	16,054	32,108	16,054	321,088
" ...	Tunnel No. 1, N. dip, Lansford basin No. 2,	85,636	51 382					
" ...	Tunnels Nos. 1 and 2, N. dip, Lansford basin No. 1,	1,093.755	656,253					
" ..	Tunnel No. 2, S. dip, Lansford basin No. 2,	153 576	92 146	......	15 358	7.678	......	38,394
" ..	Slope No. 3, S. dip, Hell Kitchen basin,	639,110	396,248	......	31,955	31,956	......	178,951
5-Foot,	Tunnel No. 1, S. dip, Hell Kitchen basin,	81 883	57,283					
"	" " overturned dip, Hell Kitchen basin,	5,777	1,733					
"	" " N. dip, Greenwood basin,	36,439	18,220					
E,	Tunnel No. 1, Slope No. 1, S. dip, Hell Kitchen basin,	4 274,848	1,923,681					
" (4,)	Tunnels Nos. 1 and 2, Shaft No. 1, Slope No. 4, N. and S. dips, shaft anticlinal,	2 710.411	1,870.183	......	94 865	284,593	94,865	365 905
" ...	Tunnel No. 1, N. dip, Lansford basin No. 1,	669 525	267.810					
" ...	Slope No. 3, S. dip, Hell Kitchen basin,	1 655 208	1,026,229	165 521	66 208	66,208	.....	331,042
	Total,	14,147 705	8 209,793					

This colliery embraces all of the mine workings at Nesquehoning.

The boundaries of this colliery are clearly defined on the mine map, (see sheets Nos. I and II,) except in one particular. There is a tunnel driven from the Red Ash gangway, west of the foot of Slope No. 3, north to the Mammoth bed. All the coal taken out of this gangway is hauled through the tunnel and out of Slope No. 3, so that this gangway and adjoining breasts belong to Colliery No. 3. The gangway above this one, and which is driven from the level of Tunnel No. 6, is a part of Colliery No. 6.

TABLE No. VII.—*Colliery No. 4.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of Coal which can still be mined. Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	Per ct. of coal which cannot be mined.
		Acres.	*Acres.*		*Feet.*	*Feet.*						
E, . . .	Slope No. 4, N. dip, Bull Run basin, ...	36.86	73.79	63	42	22	51	. . .	4½	8½	. . .	36
	Total, ...						(51 average.)					

Table No. VIII.—*Colliery No. 4.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
E, . . .	Slope No. 4, N. dip, Bull Run basin, . . .	3,206,175	1,635,149	. . . . .	144,278	272,525	. . . . .	1,154,223
	Total, ...	3,206,175	1,635,149	. . . . .	144,278	272,525	. . . . .	1,154,223

Colliery No. 4 includes all the mine workings below water level of Tunnel No. 5, west of Slope No. 7. The western limit of the colliery is at the pillar west of Tunnel No. 5, and which separates it from Colliery No. 9 on the west.

TABLE NO. IX.—*Colliery No. 5.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acrs.	*Acrs*		*Feet.*	*Feet.*						
F, . . .	Tunnel No. 5, N. dip Bull Run basin, ...	5.68	9.07	73°	10	4	60	. . .	. . .	20	. . .	20
E, . . .	Tunnel No. 5 and slope No. 7 N. and S. dips Bull Run Basin and N. dip Lansford Basin No. 1, ...	73.21	151.77	60°	21	12	69	. . .	3	2	1	25
	Total, ...						(68.8 average.)					

TABLE NO. X—*Colliery No. 5.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
F, . .	Tunnel No. 5, N. dip Bull Run Basin, . .	71,653	42,992	. . . . .	. . . . .	14,331	. . . . .	14,330
E, . . .	Tunnel No. 5 and slope No. 7 N. and S. dips Bull Run Basin and N. dip Lansford Basin No. 1, ...	3,596,949	2,481,895	. . . . .	107,909	71,939	35,969	899,237
	Total, ...	3,668,602	2,524,887	. . . . .	107,909	86,270	35,969	913,567

Colliery No. 5 includes all workings above water level of Tunnel No. 5 and those below water level east of Slope No. 7. The western limit of the colliery is at the pillar west of Tunnel No. 5 which separates it from Colliery No. 9 on the west. It is difficult to assign an average dip to the Mammoth bed for the entire colliery, on account of the flat dips at the eastern end, where the gangways pass around the Bull Run basin and Coaldale anticlinal.

TABLE NO. XI.—*Colliery No. 6.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of Coal which can Still be Mined.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acres.	*Acres.*		*Feet.*	*Feet.*						
F, . . .	Tunnel No. 6, S. dip, Greenwood basin, . .	24.30	33.32	51°	9	7	80	. . .	4	1	. . .	15
E, . . .	Tunnel No. 6 and Inside Slope, S. dip, Greenwood basin, ...	111.01	132.41	45°	50	32	62					
	Total, ...						(63 average.)					

TABLE No. XII.—*Colliery No. 6.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

NAME OF BED.	DIVISION OF COLLIERY.	Total original coal contents.	Amount of coal taken out of mine.	AMOUNT OF COAL WHICH CAN STILL BE MINED.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
F, . . .	Tunnel No. 6, S. dip, Greenwood basin, . .	460,649	368,519	. . . . .	18,426	4,607	. . . . .	69,097
E, . . .	Tunnel No. 6 and Inside Slope, S. dip, Greenwood basin, ...	8,368,312	5,188,353					
	Total.	8,828,961	5,556,872					

The workings in the F bed at this colliery are clearly defined on the map. The Mammoth bed is worked in 3 lifts, an upper and lower one as far west as Tunnel No. 7, and a middle lift to a pillar 2400 west of Tunnel No. 6. The eastern tunnel level gangway is worked to its face from Colliery No. 6. The breasts below this gangway are worked from Nesquehoning Colliery No. 3. The amount of coal which can still be taken out of the Mammoth workings is in doubt, due to the fact that the lower lifts are full of water, and it is uncertain what area is covered by the fire. It is estimated, however, that the fire at this collieay covers an area not exceeding 5 acres.

TABLE No. XIII.—*Colliery No. 7 (abandoned).*

Mine Measurements and Estimates.

NAME OF BED.	DIVISION OF COLLIERY.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	PERCENTAGE OF COAL WHICH CAN STILL BE MINED.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acrs.	*Acrs.*		*Feet.*	*Feet.*						
F, . . .	Tunnel No. 7, S. dip, Greenwood Basin, . . .	1.94	2 82	39°	9	6	50	. . .	. . .	. . .	. . .	50
E, . . .	Tunnel No. 7, S. dip, Greenwood Basin, . . .	24.24	33.60	45°	45	24	60	. . .	4	6	10	20
	Total, ...						(59.8 average.)					

TABLE NO. XIV—*Colliery No. 7 (abandoned).*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
F, . . .	Tunnel No. 7, S. dip, Greenwood Basin, .	33,417	16,708	. . . . .	. . . . .	. . . . .	. . . . .	16,709
E, . . .	Tunnel No. 7. S. dip, Greenwood Basin, .	1,592,640	955,584	. . . . .	63,705	95,559	159,264	318,528
	Total, ...	1,626,057	972,292	. . . .	63,705	95,559	159,264	335,237

The F or Lower Red Ash bed was worked to a limited extent at this colliery, in a gangway driven east and west from the tunnel. To the east of the tunnel the Mammoth (E) bed was worked in a tunnel level gangway to a pillar 2200 and which separates this colliery from No. 6. The same gangway is extended west to Tunnel No. 8. Half of the coal mined in this gangway between a point 2100 east of Tunnel No. 8 and Tunnel No. 7 was taken out of No. 7 and the other half out of No. 8.

TABLE NO. XV.—*Colliery No. 8.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of Coal which can Still be Mined.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acres.	*Acres.*		*Feet.*	*Feet.*						
F, . . .	Tunnel No. 8, S. dip, Greenwood basin, . . .	11.18	14.90	42°	9	4.5	75	. . .	. . .	. .	. . .	25
E, . . .	Tunnel No. 8 and Inside Slope, S. dip, Greenwood basin.	123.56	173.38	45°	53	29	55	. . .	4	4	8	29
	Total, ...						(55 average.)					

TABLE NO. XVI.—*Colliery No. 8.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
F, . . .	Tunnel No. 8, S. dip, Greenwood basin, .	132,424	99,318	. . . . .	. . . . .	. . . . .	. . . . .	33,106
E, . . .	Tunnel No. 8 and Inside Slope, S. dip, Greenwood basin, ...	9,930,339	5,461,686	. . . . .	397,213	397,213	794,428	2,879,799
	Total, ...	10,062,763	5,561,004	. . . . .	397,213	397,213	794,428	2,912,905

Both the Mammoth and Red Ash (F) beds have been worked from this colliery. The workings in the Mammoth bed extend 3400 west of the tunnel, to a pillar between Collieries Nos. 8 and 10: this pillar is cut by the line of Section No. 9 on Mine sheet No. III. To the east of the tunnel the two lower gangways of Colliery No. 8 extend 4650 to a pillar, which lies 400' west of Tunnel No. 7. The upper gangway is driven from tunnel to tunnel. Half of the coal mined in this lift between a point 2100 east of Tunnel No. 8 and Tunnel No. 7 was taken out of No. 7 and the other half out of No. 8. The position of the Red Ash workings at this colliery are clearly defined on the map.

TABLE No. XVII.—*Colliery No. 9.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined. Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	Percentage of coal which cannot be mined.
		Acres.	*Acres.*		*Feet.*	*Feet.*						
G, ...	Tunnel No. 9, N. dip, Bull Run basin, . . .	3.27	8.73	77°	9	7.5	15					
F, ...	Tunnels Nos. 9 and 3, N. dip, Bull Run basin,	2.54	3.24	38°	10	8	70					
E, ...	Tunnel No. 9, Inside Slope, Tunnels 3 and 4, N. dip, Bull Run basin, ...	104.24	160 05	45°	50	25	61	3	8	6	. . .	22
	Total, ...						(60 average.)					

TABLE NO. XVIII.—*Colliery No. 9.*

Tons of Coal Originallg Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
G, ...	Tunnel No. 9, N. dip, Bull Run basin, . .	129,313	19,396					
F, ...	Tunnels Nos. 9 and 3, N.dip Bull Run basin,	51,192	35,834					
E, ...	Tunnel No. 9, Inside Slope, Tunnels 3 and 4, N. dip Bull Run basin, ...	7,902,469	4,820,506	237,074	632,198	474,148	. . . . .	1,738,543
	Total, ...	8,082,974	4,875,736					

This colliery lies entirely to the north of the Summit Hill anticlinal. The Mammoth bed workings extend 5600′ east of the tunnel to a pillar which separates this colliery from Nos. 4 and 5. To the west of the tunnel the Mammoth bed workings extend to the Summit Hill mine in two gangways; a lower one 4100′ long and an upper one 700 long.

TABLE No. XIX.—*Summit Hill Colliery (abandoned).*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of Coal which can still be Mined.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acres.	*Acres.*		*Ft.*	*Ft.*						
E, . . .	Areas not touched by fire and mined from slopes Nos. 1 and 2 and Spring Tunnel, Summit Hill basin and anticlinal, ...	96.86	105.52	18°	60	45	60					
	Quarry workings in vicinity of slopes Nos. 1 and 2, Summit Hill basin and anticlinal, . .	63.82	69.56	0°	60	45	60					
	Areas on fire in vicinity of and mined from slopes Nos. 1 and 2 and Spring Tunnel, Summit Hill basin and anticlinal, ...	55.64	57.28				60					
	Total, ...						(60 average.)					

TABLE NO. XX.—*Summit Hill Colliery (abandoned).*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
E, . . .	Areas not touched by fire and mined from slopes Nos. 1 and 2 and Spring Tunnel, Summit Hill basin and anticlinal,	9,378,090	5,626,854					
	Quarry workings in vicinity of slopes Nos. 1 and 2, Summit Hill basin and anticlinal,	6,182,145	3,709,287					
	Areas on fire in vicinity of and mined from slopes Nos. 1 and 2 and Spring Tunnel, Summit Hill basin and anticlinal, . . .	5,090,760	3,054,456					
	Total, ...	20,650,995	12,390,597					

Summit Hill colliery includes all the strippings which have been made on the Summit Hill anticlinal and the underground workings in the Summit Hill basin. This colliery is bounded on the north and west by the workings of Colliery No. 9.

TABLE No. XXI—*Colliery No. 10.*

Mine Measurements and Estimates.

Name of Bed.	Division of Colliery.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined. Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	Percentage of coal which cannot be mined.
		Acrs.	*Acrs.*		*Feet.*	*Feet.*						
E, . . .	Tunnel No. 10, Inside Slope, and Greenwood Slope No. 2, S. dip, and bottom of Greenwood basin, ...	78.76	99.84	43°	52	30	58	3	7	4	1	27
Cross-cut,	Greenwood Slope No 2, S. dip, Greenwood basin, ...	2.01	2.48	41°	9	6	80	. . .	. . .	. . .	. . .	20
D, . . .	Greenwood Slope No. 2, S. dip, Greenwood basin, ...	6.19	7.55	40°	7	5.5	60	. . .	. . .	. . .	. . .	40
	Total, ...						(58 average.)					

TABLE NO. XXII.—*Colliery No. 10.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

NAME OF BED.	DIVISION OF COLLIERY.	Total original coal contents.	Amount of coal taken out of mine.	AMOUNT OF COAL WHICH CAN STILL BE MADE.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
E, . .	Tunnel No. 10, Inside Slope, and Greenwood Slope No. 2, S. dip, and bottom of Greenwood basin, . .	5,915,520	3,431,001	177,466	414,087	236,621	59,155	1,597,190
Cross-cut,	Greenwood Slope No. 2, S. dip, Greenwood basin, . . .	29,388	23,510	. . . . .	. . . . .	. . . . .	. . . . .	5,878
D, . . .	Greenwood Slope No. 2, S. dip, Greenwood basin, ...	82,011	49,206	. . . . .	. . . .	. . . . .	. . . . .	32,805
	Total, ...	6,026,919	3,503,717	177,466	414,087	236,621	59,155	1,635,873

The E, Cross-cut, and D beds have all been worked from this colliery, the E bed being worked in three lifts from 600′ above tide to outcrop. The upper lift gangway is on a level with Tunnel No. 10 (958′); east of the tunnel two lifts extend to the pillar between this and No. 8 Colliery. The upper lift is worked about ⅔ds of the distance from the gangway to the outcrop. The 3d lift breasts are only worked 2250′ east of the tunnel. The gangway is, however, driven to the pillar. West of the tunnel two upper lifts extend 2600′ to Greenwood Slope No. 2 The breasts are worked up to the outcrop. The 3d or lowest gangway has been driven 3200′ west of the tunnel. The breasts have only been worked to a distance of 1675′ from the tunnel. There was also shipped from this colliery the coal from about 11 acres, mined from what has been designated as the "south-east gangway" which lies north of Greenwood Slope No. 1 and the Old Slope, both sunk in the F bed, and also from about one acre lying to the south of this gangway on the south dip of the Lansford basin. The coal from this latter area was carried through the inside tunnel located 2250′ west of Slope No. 2. The length of the "south-east gangway" is 2800′; its western end is within 400′ of Greenwood tunnel. About two acres of the Cross-cut bed was worked from this colliery from a tunnel located 2250′ west of Greenwood Slope No. 2 The D bed has been worked one lift in Greenwood Slope No. 2 workings, from the same tunnel from which the Cross-cut bed was worked. The gangway extends about 500′ east and 900′ west of the tunnel. The coal mined was shipped from No. 10 Colliery About six acres was mined over.

TABLE NO. XXIII.—*Colliery No. 11.*

Mine Measurements and Estimates.

NAME OF BED.	DIVISION OF COLLIERY.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	PERCENTAGE OF COAL WHICH CAN STILL BE MINED.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acres.	*Acres.*		*Feet.*	*Feet.*						
Red Ash, No. 1,	Tunnel No. 11, N. dip, Sharp Mountain basin,	1.01	18.09	. .	9	4	50	5	10	15	. . .	20
Red Ash, No. 2,	Tunnel No. 11, N. dip, Sharp Mountain basin,	.50	9.09	. .	13	9	50	. . .	. . .	. . .	. . .	50
E, ...	Tunnel No. 11, N. dip, Sharp Mountain basin,	2.15	51.51	. .	26	12	60	. . .	10	4	. . .	26
E, ...	Tunnel No. 2, N. dip, Foster Tunnel basin, S. dip, Dry Hollow basin, ...	5.74	7.50	. .	25	14	32	13	3	7	. .	45
D, ...	Tunnel No. 11, N. dip, Sharp Mountain basin,	66	15.69	. .	18	7	48	8	. . .	14	10	20
	Total, ...						(54 average.)					

Table No. XXIV.—*Colliery No. 11.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Red Ash, No. 1,	Tunnel No. 11, N. dip, Sharp Mountain basin,	142,911	71,455	7,145	14,292	21,437	. . . . .	28,582
" No. 2,	Tunnel No. 11, N. dip, Sharp Mountain basin,	161,575	80,787	. . . . .	. . . . .	. . . . .	. . . . .	80,788
E, ...	Tunnel No. 11, N. dip, Sharp Mountain basin,	1,220,787	732,472	. . . . .	122,079	48,832	. . . . .	317,404
E, ...	Tunnel No. 2, N. dip, Foster Tunnel basin, S. dip, Dry Hollow basin,	207,375	66,360	26,959	6,221	14,516	. . . . .	93,319
D, ...	Tunnel No. 11, N. dip, Sharp Mountain basin, ...	216,914	104,119	17,353	. . . . .	30,368	21,691	43,383
	Total, ...	1,949,562	1,055,193	51,457	142,592	115,153	21,691	563,476

The boundaries of this colliery are clearly defined on the map, as they do not join the workings of any other colliery. What has been named the D bed here is evidently the representative of the C bed (See page 103).

TABLE No. XXV.—*Greenwood Colliery.*

Mine Measurements and Estimates.

Name of bed.	Division of colliery.	Surface area under development.	Bed area under under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	Percentage of coal which can still be mined.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acres.	*Acres.*		*Feet.*	*Feet.*						
G,	Levan's Slope, S. dip, Lansford Basin,	3.05	5.14	57°	3	2	60					
F,	" " "	135.04	204.60	57°	12	10	50					
E,	Levan's Drift and Greenwood Slope No. 4, S. dip, Lansford Basin,	36.63	50 79	57°	25	18	70					
"	Greenwood Slope No. 1, S. dip, Lansford Basin,	4.82	7 03	51°	20	15	70					
"	Slope No. 2, S. dip, Greenwood Basin,	41.04	52.73	43°	37	20	50	....	3	2	30	15
Cross-Cut,	" " " and Tunnel No. 1, S. dip, Lansford Basin,	13.26	29.14	41°	9	6	80	....	....	....	....	20
D,	Levan's Slope and Drift. S. dip, Lansford Basin,	45.73	57.17	57°	9	7	60					
"	Slope No. 2. S. dip, Greenwood Basin,	8.65	10.26	40°	7	5.5	70	....	....	....	...	30
C,	Levan's Drift, S. dip, Lansford Basin,	2.14	3.64	57°	8	6	60					
B,	" " "	.17	.17	57°	6	3	50					
A,	" " "	8.68	13.35	55°	10	8	70					
	Total,						(57 average.)					

TABLE NO. XXVI.—*Greenwood Colliery.*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars	Breast pillars.	Chain pillars.	
		Tons.	*Tons.*	*Tons*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
G,	Levan's Slope, S. dip, Lansford Basin,	20.303	12,181					
F,	" " "	4,040 850	2,020,425					
E,	Levan's Drift & Greenwood Slope No. 4, S. dip, Lansford Basin,	1,805,584	1,263 908					
"	Greenwood Slope No. 1, S. dip, Lansford Basin,	208 263	145,784					
"	Slope No. 2, S. dip, Greenwood Basin,	2,082 835	1,041,417	....	62,485	41,656	624,851	312,426
Cross-cut,	" " " and Tunnel No. 1, S. dip, Lansford Basin,	346,183	276,946	....	....	....	...	69,237
D,	Levan's Slope and Drift, S. dip, Lansford Basin,	790 375	474 225					
"	Slope No. 2, S. dip, Greenwood Basin,	111,449	78.014	....	....	....	....	33,435
C,	Levan's Drift, S. dip, Lansford Basin,	43 134	25,880					
B,	" " "	1 007	503					
A,	" " "	210,930	147,651					
	Total,	9,660 913	5.486,934					

At this colliery 8 different coal beds have been mined, which is a greater number than at any other colliery in the Panther Creek Valley.

The G bed is worked from the tunnel driven from the F bed at the foot of Levan's Slope. The gangway in this bed has been driven 375′ east of the tunnel and 650′ west. The F bed has been worked from Levan's No. 1 and Old Slopes. West from Levan's Slope one gangway has been driven a distance of 660′. East, two gangways have been driven. The upper is 4750′ long and extends to within about 1000′ of Slope No. 1. The lower is 2550′ long and has been driven to the pillar between the east breast of this gangway and that of a gangway driven from Slope No. 1. West of Slope No. 1 two gangways have been driven; an upper for a distance of 2500′ and a lower for a distance of 1900′. East of the same slope three gangways have been driven; the upper for a distance of 7200′, the middle for the same distance, and the lower for 4200′. The Mammoth (E) bed has been worked from two gangways driven west from Slope No. 4; the upper for a distance of 5200′, opening to-day at Levan's drift, and a lower for 2150′. This bed has been further worked from an underground tunnel driven north from the F bed at a point about 150′ west of Slope No. 1. A gangway has been driven in the bed east from the end of this tunnel, for a distance of 1700′. The Mammoth (E) bed has also been mined from two gangways driven for a distance of 4200′ to the end of the Greenwood basin, west of Slope No. 2. The Mammoth coal, mined from an inside tunnel 2250′ west of Slope No. 2 and from the "South-east gangway," was shipped from Colliery No. 10. Greenwood Colliery includes all workings in the Cross-cut bed from Tunnel No. 1 and Slope No. 2, with the exception of about 1-15th of the entire exploited area of the Cross cut bed, which was mined from the inside tunnel and shipped from Colliery No. 10. The D bed has been worked from Levan's Slope, the D drift, and from Slope No. 2. The coal mined from the lowest and most southern gangway, at the end of the inside tunnel, 2250′ west of Slope No. 2, was shipped from Colliery No. 10. The C, B, and A beds have only been worked in the Levan's drifts driven east from the Locust Mountain gap. The only locality in the Panther Creek basin where any coal has been mined below an elevation of 500′ above tide level is at Greenwood Slope No. 1 where the F (Lower Red ash) and Mammoth (E) gangways have an elevation of about 435′ above tide.

TABLE No. XXVII.—*Sharp Mountain Colliery (abandoned).*

Mine Measurements and Estimates.

NAME OF BED.	DIVISION OF COLLIERY.	Surface area under development.	Bed area under development.	Average dip of bed.	Average thickness of bed.	Average thickness of coal.	Percentage of coal taken out of mine.	PERCENTAGE OF COAL WHICH CAN STILL BE MINED.				Percentage of coal which cannot be mined.
								Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Acrs.	*Acrs.*		*Feet.*	*Feet.*						
E, ...	Slope, overturned N. dip, Sharp Mountain basin,	.83	34.29	85°	25	16	60	. . .	. . .	. . .	. . .	40
Cross-Cut, . .	Slope, overturned N. dip, Sharp Mountain basin,	.96	40.01	85°	9	6	60	. . .	. . .	. . .	. . .	40
D, ...	Slope, overturned N. dip, Sharp Mountain basin,	.14	5.37	85°	. . .	4(?)	60	. . .	. . .	. . .	. . .	40
C, ...	Randall's drift, overturned N. dip, Sharp Mountain basin, ...	.59	11.71	85°	16	8	60	. .	. . .	. . .	. . .	40
	Total, ...						(60 average.)					

TABLE NO. XXVIII.—*Sharp Mountain Colliery (abandoned.)*

Tons of Coal Originally Contained, Mined, and still to be Mined.

Name of Bed.	Division of Colliery.	Total original coal contents.	Amount of coal taken out of mine.	Amount of Coal which can Still be Mined.				Amount of coal which cannot be mined.
				Unfinished breasts.	Gangway pillars.	Breast pillars.	Chain pillars.	
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
E,	Slope, overturned N. dip, Sharp Mountain basin,	1,083,564	650,138	. . . . .	. . . . .	. . . . .	. . . . .	433,426
Cross-Cut,	Slope, overturned N. dip, Sharp Mountain basin,	474,118	284,470	. . . . .	. . . . .	. . . . .	. . . . .	189,648
D,	Slope, overturned N. dip, Sharp Mountain basin,	42,423	25,453	. . . . .	. . . . .	. . . . .	. . . . .	16,970
C,	Randall's drift, overturned N. dip, Sharp Mountain basin,	185,018	111,010	. . . . .	. . . . .	. . . . .	. . . . .	74,008
	Total,	1,785,123	1,071,071	. . . . .	. . . . .	. . . . .	. . . . .	714,052

All the workings along the Sharp Mountain and east of the Little Schuylkill River have been included in this colliery.

TABLE NO. XXIX.—*Showing the number of tons which have been taken out of the different beds at each Colliery and in the entire Panther Creek basin up to January 1, 1883, and the number of tons still remaining for future mining.*

NAME OF BED.	Sharp Mountain Colliery.	Greenwood Colliery.	No. 11 Colliery.	No. 10 Colliery.	Summit Hill Colliery.	No. 9 Colliery.	No. 8 Colliery.	No 7 Colliery.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
G, or Upper Red Ash, ...	. . . . .	12,181	.	. . . .	. . . .	19,396		
F, or Red Ash, ...	. . . .	2,020,425	152,242	. . . . .	. . . . .	35,834	99,318	16,708
E, (Top Split,) . Cross-Cut, (Middle Split,) D, (Bottom Split,) } Mammoth	960,061	3,280,294	902,951	3,503,717	12,390,597	4,820,506	5,461,686	955,584
C, ...	111,010	25,880						
B, ...	. . . .	503						
A, ...	. . . . .	147,651						
Lykens Valley, ...								
	1,071,071	5,486,934	1,055,193	3,503,717	12,390,597	4,875,736	5,561,004	972,292

TABLE NO. XXIX.—*Continued.*

NAME OF BED.	No. 6 Colliery.	No. 5 Colliery.	No. 4 Colliery.	No. 3, or Nesquehoning Colliery.	Hacklebarney Tunnel.	Number of tons taken out.	Number of tons left in.	Total original coal contents under area covered by Mine sheets Nos. I, II, and III.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Jock,	. . .	. . .	. . .	. . .	. . .	. . .	18,153,490	18,153,490
Washington,	. . .	. . .	. . .	. . .	. . .	. . .	8,940,331	8,940,331
G, or Upper Red Ash,	. . .	. . .	. . .	105,551	. . .	137,128	36,611,035	36,748,163
F, or Red Ash	368,519	42,992	. . .	2,939,103	. . .	5,675,141	124,704,345	130,379,486
Five Foot,	. . .	. . .	. . .	77,236	. . .	77,236	4,105,695	4,182,931
E, (Top Split,)								
Cross-cut, (Middle Split,) } Mammoth,	5,188,353	2,481,895	1,635,149	5,087,903	1,157,745	47,826,441	524,543,667	572,370,108
D, (Bottom Split,)								
C,	. . .	. . .	. . .	. . .	. . .	136,890	128,119,670	128,256,560
B,	. . .	. . .	. . .	. . .	114,844	115,347	71,839,353	71,954,700
A,	. . .	. . .	. . .	. . .	. . .	147,651	61,863,711	62,011,362
Lykens Valley,								
	5,556,872	2,524,887	1,635,149	8,209,793	1,272,589	54,115,834	978,881,297	1,032,997,131

TABLE NO. XXX.—*Showing the total original contents, in tons, of the area worked over at each Colliery up to January, 1883; the number of tons mined; and partial estimates as to the number of tons which are known to be still available.*

NAME OF COLLIERY.	Total original coal contents.	Amount of coal taken out of mine.	Amount of coal which can still be mined.*	Amount of coal which cannot be mined.*
	Tons.	*Tons.*	*Tons.*	*Tons.*
Hacklebarney Tunnel, (abandoned,) . .	2,492,173	1,272,589	. . . . . .	. . . . . .
Colliery No. 3, (Nesquehoning,)	14,147,705	8,209,793	. . .	. . . . . .
Colliery No. 4, ...	3,206,175	1,635,149	416,803	1,154,223
Colliery No. 5, ...	3,668,602	2,524,887	230,148	913,567
Colliery No 6,	8,828,961	5,556,872	.	. .
Colliery No. 7, (abandoned,)	1,626,057	972,292	318,528	335,237
Colliery No. 8,	10,062,763	5,561,004	1,588,854	2,912,905
Colliery No. 9,	8,082,974	4,875,736	. . . . .	. .
Summit Hill, (abandoned,)	20,650,995	12,390,597	.	.
Colliery No. 10, . . .	6,026,919	3,503,717	887,329	1,635,873
Colliery No. 11,	1,949,562	1,055,193	330,893	563,476
Greenwood, (abandoned,) .	9,660,913	5,486,934	. . . . . .	. . . . . .
Sharp Mountain, ...	1,785,123	1,071,071	. . . .	. . . . .
	92,188,922	54,115,834	. . . . . .	. . . . . .

From an inspection of all the facts obtained at the collieries where the above estimates have been made, it is believed that in the exploited areas *at least 11* per cent of the total original coal contents can still be mined, leaving only 30 per cent, which will be ultimately lost in the mines. According to this the totals of the two latter columns would be 10,000,000 ± and 28,000,000 ± tons respectively; or, in other words, if no gangways or breasts should have been driven since January 1st. 1883, beyond the area which at that time was exploited at each colliery, it is believed that

*Where blanks exist in these two columns it was impossible to obtain reliable facts to make any estimates.

10,000,000± tons of coal could still be mined out of the unfinished breasts and from the gangway, breast, and chain pillars, in what has previously been considered the exhausted mines of the Panther Creek Valley.

This estimate is low as compared with the experience of the Lehigh Coal and Navigation Company, in mining over portions of their mines during the past 4 or 5 years, which prior to that time were supposed to have been worked out. It is low also, as compared with the recent estimates made by the Survey, for special divisions of the different collieries. (See tables of Mine Measurements and Estimates). Large areas were found in the old portions of the mines at each colliery, which could not be visited, on account of being closed by roof falls, water or gas, and in which, consequently, no estimate could be made of the amount of coal which might still be won. For this reason, I have made a minimum estimate, in stating that 11 per cent of the coal originally contained in the old mined areas, might still be obtained by a more careful and systematic method of mining.

From January 1st. 1881, to January 1st. 1883, 66 per cent. of the coal taken from the mines of the Panther Creek basin was converted into fuel and 34 per cent was sent to the dirt banks (See table XXXII); so that, of the coal still to be won from the old mines, 6,600,000 tons should be made available for fuel, if the practice and experience in the preparation of coal shall remain the same as it was in those 2 years.*

During the history of the Panther Creek Valley, 27 per cent of the coal originally contained, in the exploited areas, has been produced as fuel (See table XXXIV); if 6,600,000 tons shall still be procured, the percentage of marketable coal which will ultimately be produced from the old mines will be 34; instead of 27 per cent which has so far been obtained.

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* If the most *liberal* allowance be made for unforseen difficulties in working in the old mines, there should *certainly* be produced at least 3,400,000 tons of marketable coal from the now abandoned mines.

TABLE NO. XXXI.—*Showing the Total Production of all the Mines in the Panther Creek Valley, from their origin to January 1, 1883; compiled from published annual reports of the Lehigh Coal and Navigation Company, and from additional data furnished by Mr. Joseph S. Harris, President.*

YEAR.	Summit Mines.	Rhume Run.	East Lehigh, or Old Tunnel.	Tamaqua.	No. 2 Tunnel.	Dirt Heaps.	F Bed.	Total.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1820, .	365	. . .	. . .	. . .	. . .	. . .	. . .	365
1821, .	1,073	. . .	. . .	. . .	. . .	. . .	. . .	1,073
1822, .	2,440	. . .	. . .	. . .	. . .	. . .	. . .	2,440
1823, .	5,823	. . .	. . .	. . .	. . .	. . .	. . .	5,823
1824, .	9,541	. . .	. . .	. . .	. . .	. . .	. . .	9,541
1825, .	28,393	. . .	. . .	. . .	. . .	. . .	. . .	28,393
1826, .	31,280	. . .	. . .	. . .	. . .	. . .	. . .	31,280
1827, .	27,770	. . .	. . .	. . .	. . .	. . .	. . .	27,770
1828,	33,150	. . .	. . .	. . .	. . .	. . .	. . .	33,150
1829, .	25,110	. . .	. . .	. . .	. . .	. . .	. . .	25,110
1830, .	43,000	. . .	. . .	. . .	. . .	. . .	. . .	43,000
1831, .	44,500	. . .	. . .	. . .	. . .	. . .	. . .	44,500
1832, .	77,292	. . .	. . .	. . .	. . .	. . .	. . .	77,292
1833, .	124,508	. . .	. . .	. . .	. . .	. . .	. . .	124,508
1834, .	106,500	. . .	. . .	. . .	. . .	. . .	. . .	106,500
1835, .	131,250	. . .	. . .	. . .	. . .	. . .	. . .	131,250
1836, .	146,738	. . .	. . .	. . .	. . .	. . .	. . .	146,738
1837, .	200,000	. . .	. . .	. . .	. . .	. . .	. . .	200,000
1838, .	154,693	. . .	. . .	. . .	. . .	. . .	. . .	154,693
1839, .	142,507	. . .	. . .	. . .	. . .	. . .	. . .	142,507
1840, .	102,264	. . .	. . .	. . .	. . .	. . .	. . .	102,264
1841, .	78,164	. . .	. . .	. . .	. . .	. . .	. . .	78,164
1842, .	163,762	. . .	. . .	. . .	. . .	. . .	. . .	163,762
1843,	105,043	33,783	. . .	. . .	. . .	. . .	. . .	138,826
1844, .	168,441	50,804	. . .	. . .	. . .	. . .	. . .	219,245
1845, .	184,484	73,256	. . .	. . .	. . .	. . .	. . .	257,740
1846, .	165,011	109,652	. . .	10,150	. . .	. . .	. . .	284,813
1847, .	201,951	132,978	. . .	16,746	. . .	. . .	. . .	351,675
1848, .	214,839	121,730	. . .	24,050	. . .	. . .	. . .	360,619
1849, .	276,501	102,784	. . .	14,522	. . .	. . .	. . .	393,807
1850, .	330,447	93,811	. . .	. . .	. . .	. . .	. . .	424,258
1851, .	393,353	87,471	. . .	. . .	. . .	. . .	. . .	480,824
1852, .	429,786	80,620	. . .	. . .	. . .	. . .		510,406
1853, .	393,255	83,721	. . .	. . .	. . .	. . .	19,929	496,905
1854, .	413,049	92,138	10,731	233	. . .	. . .	28,660	544,811
1855, .	312,354	79,855	35,190	. . .	. . .	. . .	22,413	449,812
1856, .	284,711	64,291	33,141	7,168	. . .	. . .	11,114	400,425
1857, .	306,396	53,834	20,182	15,839	. . .	. . .	4,500	400,751
1858, .	284,704	57,821	42,969	32,729	7,673	. . .	. . .	425,896

Table No. XXXI—*Concluded.*

Year.	Summit Mines.	Rhume Run.	East Lehigh, or Old Tunnel.	Tamaqua.	No. 2 Tunnel.	Dirt Heaps.	F Bed.	Total.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1859, .	402,030	51,859	36,651	56,205	71	. . .	. .	546,816
1860, .	386,452	55,959	31,674	43,072	. . .	. . .	. . .	517,157
1861, .	327,706	45,400	23,933	13,838	. . .	. . .	. . .	410,877
1862, .	198,459	29,124	13,862	9,393	. . .		. . .	250,838
1863, .	380,303	80,168	30,388	25,817	. . .	584	. . .	517,260
1864, .	379,727	92,738	. . . .	32,685	. . .	12,030		517,180
1865,	408,172	79,753	. . . .	19,535	. . .	3,543	6,022	517,025
1866, .	400,000	. . . .	. . .	. . . .	. . .	. . .	. .	400,000
1867, .	370,204	. . . . .	. . . .	. . . .	. . .		. . .	370,204
Totals,	9,397,501	1,753,550	278,721	321,982	7,744	16,157	92,638	11,868,293
				Green-wood Coal Co.				
1868, .	375,395	56,140	. . . .	22,285	. . .	. . .	. . .	453,820
1869, .	412,609	56,401	. . . .	3,400	. . .	. . .	. . .	472,410
1870, .	261,187	27,616	. . . .	8,671	. . .	. . .	. . .	297,474
1871, .	462,128	48,933	. . . .	7,739	. . .	. . .	. . .	518,800
1872, .	498,866	67,858	. . . .	60,596	. . .	. . .	. . .	627,320
1873, .	451,549	74,074	. . . .	35,617	. . .	. . .	. . .	561,240
1874, .	. . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	572,470
1875, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	397,428
1876, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	606,773
1877, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	550,519
1878, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	430,987
1879, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	705,303
1880, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	554,937
1881, .	. . . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	648,148
1882, .	. . . .	. . . . .	. . . .	. . . .	. . .	. . .	. . .	837,968
Totals,	11,859,235	2,084,572	278,721	460,290	7,744	16,157	92,638	20,103,890
Production from Greenwood Colliery, not reported above, .								2,831,692
Small coals produced, not reported above, .								700,000
Add 5 per cent* of the total production for coal consumed at collieries, not reported above, ...								1,181,779
Total production Panther Creek Valley to January 1, 1883,								24,817,361

*I believe that more than 5 per cent should have been added here for colliery consumption.—C. A. A.

TABLE NO. XXXII.—*Showing the total number of cubic feet of Commercial Coal produced, and of Refuse sent from breakers to dirt banks, and directly from mines to dirt banks, by the Lehigh Coal and Navigation Company, from the Panther Creek Basin, for two years, from January 1, 1881, to January 1, 1883. Reported by Mr. Wm. D. Zehner, Superintendent.*

NAME OF COLLIERY.	TOTAL MARKETABLE COAL PRODUCED.		REFUSE SENT FROM BREAKERS TO DIRT BANKS.			REFUSE SENT FROM MINE TO DIRT BANKS.			TOTAL REFUSE SENT TO DIRT BANKS.			Total coal and refuse hauled out of mines—cubic feet.
	Cubic feet.*	Percentage of total hauled out of mines.	Cubic feet.*	Percentage of total hauled out of mines.	Percentage of total marketable coal produced.	Cubic feet.	Percentage of total hauled out of mines.	Percentage of total marketable coal produced.	Cubic feet.	Percentage of total hauled out of mines.	Percentage of total marketable coal produced.	
Colliery No. 3, ...	12,355,840	79	1,804,166	12	15	1,399,531	9	11	3,203,697	21	26	15,559,537
Colliery No. 4, ...	8,737,440	75	2,716,760	23	31	256,932	2	3	2,973,692	25	34	11,711,132
Colliery No. 5, ...	6,801,120	58	4,674,780	39	69	345,250	3	5	5,020,030	42	74	11,821,150
Colliery No. 6, . . .	7,965,040	57	5,671,360	41	71	238,845	2	3	5,910,205	43	74	13,875,245
Colliery No. 8, . .	11,213,920	63	6,274,180	35	56	315,900	2	3	6,590,080	37	59	17,804,000
Colliery No. 10, . . .	10,278,960	76	2,261,940	17	22	953,504	7	9	3,215,444	24	31	13,494,404
Colliery No. 11, . . .	8,657,360	54	6,218,640	38	72	1,286,415	8	15	7,505,055	46	87	16,162,415
	66,009,680†	66	29,621,826	29	45	4,796,377	5	7	34,418,203	34	52	100,427,883

*The number of cubic feet, of coal and refuse, sent from the mines to the breakers may be found, by the addition of the cubic feet contained in these two columns, respectively. †See foot note Table XXXIII.

TABLE No. XXXIII.—*Showing the distribution of the coal production of the Lehigh Coal and Navigation Company into sizes larger than Buckwheat, and Buckwheat shipped to market, and coal consumed at Collieries, for two years, from January 1, 1881, to January 1, 1883. Reported by Mr. Wm. D. Zehner, Superintendent.*

Name of Colliery.	Sizes larger than Buckwheat shipped.		Buckwheat shipped.		Consumed at Colliery.		Total marketable coal produced—Tons.
	Tons.	Percentage of total production.	Tons.	Percentage of total production.	Tons.	Percentage of total production.	
Colliery No. 3,	225,194	73	61,183	20	22,519	7	308,896
Colliery No. 4,	178,618	82	21,957	10	17,861	8	218,436
Colliery No. 5,	143,045	84	16,970	10	10,013	6	170,028
Colliery No. 6,	169,646	85	24,391	12	5,089	3	199,126
Colliery No. 8,	232,442	83	24,662	9	23,244	8	280,348
Colliery No. 10,	192,189	75	51,332	20	13,453	5	256,974
Colliery No. 11,	145,874	67	66,184	31	4,376	2	216,434
Totals,	1,287,008*	78	266,679	16	96,555	6	1,650,242

*There were shipped from Colliery No. 9, during the year 1881, 56,960 tons of coal in sizes larger than buckwheat. The mine was on fire during the greater part of the year and its production was not placed in the above report.

TABLE No. XXXIV.—*Showing the percentage of the total commercial coal contained in the exploited areas of the Panther Creek basin, that has been left in the mines, sent to the dirtbanks and produced as fuel.**

	PERCENTAGE OF COMMERCIAL COAL ORIGINALLY CONTAINED.			
	Coal left in mines; in unfinished breasts and for roof supports.	Waste coal sent directly from mines and breakers to dirt banks.	Fuel coal sent to market and consumed locally.	
Average percentages from commencement of mining to January 1, 1883, (embraces entire history of Panther Creek Valley,)	41	32	27	100
Average percentages for two years from January 1, 1881, to January 1, 1883, .	30	24	46	100

*The fuel production includes the coal which has been shipped to market and consumed at the collieries.

The averages stated in this table are for all the collieries of the Panther Creek basin. They will be found to vary very much for the individual colleries. What the actual percentages would be for each colliery, may be ascertained, by a combination of the results stated in the tables, showing the coal originally contained in the exploited area at each colliery, the amount which has been mined, and the estimate of that which can still be mined, with the facts contained in tables Nos. XXXII and XXXIII. I have not compiled such a table for each colliery, for this report of progress, from the fact that it would involve an extensive discussion of the principles and methods of mining employed, and from the additional fact that sufficient data are not at present in the possession of the Survey to enable the results which would be thus obtained, to be applied to other collieries throughout the region. As soon as similar facts are procured from other collieries, I hope to be able to consider at length the causes, kinds and amount of waste in mining anthracite coal, and to arrive at conclusions which may be applied to collieries working under special conditions. This is one of the most important and practical questions connected with the mining of anthracite, and has already been ably considered by a number of prominent engineers in the region and by Mr. Franklin Platt in report A^2, and by Dr. H. M. Chance in report AC. One of the greatest difficulties which has embarrassed such an investigation has been the want of sufficient data.

Chapter VII.

1. Composition of the Panther Creek Coals; 2. Composition of Bony Coal from Colliery No. 10; 3. Composition of the Market Sizes, Panther Creek Coals; 4. Composition of the Ash of the Panther Creek Coals; 5. Relation between the Composition of Coals and their Geological Structure.

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1. Composition of the Panther Creek Coals.

The coals of the Panther Creek basin were sampled, with a view of determining their chemical constitution, as they are mined at the collieries at the time of sampling.* Most of the specimens were obtained from the railroad cars, in the yard of the Lehigh Coal and Navigation Company, as they came from the different collieries and were ready to be shipped to market.* These cars were in every case carefully marked with the number and name of the colliery from which they came, by the company's shipping clerk.

* A great deal of coal, which is shipped to market, contains pieces of slate entirely detached from any coal. Such pieces of slate were thrown out, in collecting these specimens, before the size of the specimens was reduced, as explained.

To prevent any mistake, which would result from a car being incorrectly marked. Mr. J. C. Rutter. Mining Engineer of the company, examined the the shipping cards. Mr. Arthur Winslow, who collected* and sampled the coals, was assisted throughout by Mr. Rutter.

In order to obtain a fair average specimen of the coal bed, which is being mined at each colliery, pieces of various sizes were collected from as many of the cars as possible: with the smaller sizes a shovelful was taken from each car. After specimens had thus been obtained, in most cases from about fifteen cars from each colliery, they were dumped upon a platform and the larger pieces reduced to the size of stove or egg coal. The pile was then carefully mixed and quartered, and the diagonally opposite quarters removed. The remaining coal was re-mixed and re-quartered, the process being repeated until the original pile was reduced to about ten pounds. This quantity was then halved and each half placed in a sample bag.

In cases where two beds were mined at the same colliery, and it was desirable to obtain specimens from each bed, samples were collected directly from the mine cars before they went to the breaker. As the coal in the mine cars is mixed with dirt and slate, and is of all sizes, specimens were selected from a trip of mine cars, which, according to Mr. Rutter's judgment, represented the average character of the coal, as shipped to market from the breaker after the slate and poor coal had been removed.

The following table shows the results obtained from the chemical analyses of the different coals collected, made by Mr. Andrew S. McCreath:†

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* June 26th and 27th, 1882.

† For a comparison of the analyses of the coals of the Lehigh Coal and Navigation Company, with others in the Anthracite Region, the reader is referred to my prefatory letter.

TABLE No. I.—*Analyses of the Coals mined from the Collieries of the Lehigh Coal and Navigation Company.*

No. of specimen.	Number of Colliery and Label.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Color of ash.	Specific gravity.
1	No. 3 Colliery, Mammoth bed, (E,)	3.036	4.367	85.729	1.018	5.850	100.00	Red, white specks,	1.578
2	" 3 " Red Ash " (F,)	2.930	4.290	88.181	.556	4.043	100.00	Cream,	1.574
3	" 4 " Mammoth " (D and E,)	3.106	4.270	84.442	.492	7.690	100.00	Light cream,	1.615
4	" 5 " " " "	3.040	4.656	83.706	.542	8.056	100.00	Light cream,	1.620
5	" 6 " " " "	3.656	3 990	86.703	.505	5.146	100.00	Cream.	1.615
6	" 6 " Red Ash " (F,)	3.086	3.960	87.783	.455	4.716	100.00	Dark cream,	1.595
7	" 8 " Mammoth " (D and E,)	3.320	3.713	86 611	.423	5.933	100.00	Cream,	1.623
8	" 10 " " " (D and E,)	2.743	4.247	81.511	.623	10.876	100.00	Gray,	1.675
9	" 11 " " " (D (?) and E,)	2.706	4.684	77.986	.884	13.740	100.00	Reddish-gray,	1.688
	Average of the "Red Ash" (F) coals,	3.008	4.125	87.982	.506	4.379	....	....	1.584
	Average of the "White Ash" (Mammoth) coals,	3.087	4.275	83.813	.641	8.184	....	....	1.631

The great percentage of ash in specimens Nos. 8 and 9 may be due to the fact that the coal collected contained a great deal of the smaller market sizes (See table No. III, page 182).

The names "White Ash" and "Red Ash" have been adopted by this company, and its customers, to designate the coal mined from the Mammoth (E) and Red Ash (F) beds respectively; they do not necessarily imply that the ashes obtained from the combustion of these coals are always white or red in color (See table No. I, page 179).

Noted below are the number of cars from which the individual specimens were taken, and the size of the coal sampled:

Specimen No. 1.	Sampled from	
	3 mine cars from tunnel workings.	
	3 " " shaft "	
" *No. 2.*	Sampled from	
	3 mine cars from slope workings.	
	5 " " shaft "	
" *No. 3.*	Sampled from	
	3 market cars of egg coal.	
	8 " " broken coal.	
	2 " " lump coal.	
" *No. 4.*	Sampled from	
	3 market cars of lump coal.	
	5 " " broken coal.	
" *No. 5.*	Sampled from	
	4 mine cars.	
" *No. 6.*	Sampled from	
	4 mine cars.	
" *No. 7.*	Sampled from	
	5 market cars of broken coal.	
	5 " " egg "	
" *No. 8.*	Sampled from	
	4 market cars of buckwheat coal.	
	4 " " pea "	
	4 " " chestnut "	
	4 " " stove "	
	4 " " broken "	
" *No. 9.*	Sampled from	
	15 market cars of buckwheat coal.	
	7 " " pea "	
	3 " " broken "	

2. Composition of Bony Coal, Colliery, No. 10.

In separating the bony coal, slate, and rock from the Mammoth (E) coal, mined at Colliery No. 10, a great deal of bony coal has been thrown away, from the bad appearance it presented, as worthless. Specimens from three grades of this bony coal were carefully selected* and analyzed by Mr. McCreath, with the following results:

TABLE No. II.—*Analyses of Bony Coal thrown on the culm bank at Colliery No. 10.*

	Bone No. 1.	*Bone No. 2.*	*Bone No. 3.*
Water,	2.733	3.033	2.826
Volatile matter,	3.933	4.053	4.247
Fixed carbon,	83.115	84.173	82.083
Sulphur,	.423	1.428	.458
Ash,	9.796	7.313	10.386
Total,	100.000	100.000	100.000
Specific gravity,	1.661	1.647	1.677
Color of ash,	Cream.	Reddish-gray.	White.

Specimen No. 1 was considered to be a better fuel than No. 2, and specimen No. 2 better than No. 3.

It is remarkable to observe, that each one of these bony coals, which was thrown away on the dump as too poor to be sent to market for fuel, contained more fixed carbon than the coal which was shipped; the specimens in each case were carefully collected as averages. The results of this examination show how utterly impossible it is, to judge of the fuel value of a coal from its physical appearance alone, and how unjust the prejudices of the trade may be, which would condemn a coal because its appearance might not be pleasing to the eye. This lusterless coal, if broken into pea and buckwheat sizes, might not be distinguished by the trade from the coal having a high luster, and a great deal of coal which is now thrown on the dirt banks as worthless, all over the region, could be sold at a profit to the operator.

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3. Composition of the Market Sizes, Panther Creek Coals.

The analyses given in table No. I are of the coals care-

*By Messrs. F. A. Hill and J. C. Rutter, July 8, 1882.

fully sampled from all the sizes shipped from each colliery. No pieces of slate were included in the samples, except such as were embedded in the broken pieces of coal to be shipped. This slate could not be separated from the coal save by such tedious means as would be too inconvenient or expensive to employ. It is found in practice, after the coal is passed through the breaker and screened into special sizes for shipment, that the purity of the different sizes, as regards fixed carbon and ash, is very different. This is due in a measure to the original character of the mined coal,* but more particularly to the method of preparation, which will be described in report AC by Dr. H. M. Chance on the "Methods and Appliances for Mining Anthracite." In order to determine the composition of the company's coals sent to market, specimens of the different sizes were carefully sampled from the stock pockets in the Hauto screen building; these were analyzed by Mr. McCreath, with the following results:

TABLE No. III—*Analyses of the Market Sizes of Coal shipped by the Lehigh Coal and Navigation Company.*

Kind of Coal.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Color of ash.
Egg, . . .	1.722	3.518	88.489	.609	5.662	100	Light cream, white specks.
Stove, . . .	1.426	4.156	83.672	.572	10.174	100	Cream.
Chestnut, .	1.732	4 046	80.715	.841	12.666	100	Cream.
Pea, .	1.700	3.894	79.045	.697	14.664	100	Cream, white specks
Buckwheat,	1.690	4.058	76.918	.714	16.620	100	Cream, white specks

	Phosphorus per cent.
Egg, ...	.009
Stove, ...	.018
Chestnut, ...	.018

* If a great deal of slate is distributed in thin layers throughout the body of the coal bed, the difference between the amount of ash, in the large and small sizes of coal obtained from the bed, will not be as great, as where the body of a bed may be freer from slate, but where thicker and more distinct slate layers alternate with the coal benches. In the latter case, the slate is readily separated by hand-picking from the larger sizes, and the percentage of ash in the coal would in consequence be small; whereas, in the smaller sizes a great many small pieces of slate become inseparably (by most of the present methods) mixed up with the coal, and the percentage of ash will be found to be high.

The egg specimen was sampled from several railroad cars; the other specimens were sampled from pockets in the screen building, a number of which were filled with each of the smaller sizes.

The coals of this company pass over and through sieve-meshes of the following sizes:

		Inches.		Inches.
Broken or grate,	through	4	over	$2\frac{1}{2}$
Egg,	"	$2\frac{1}{2}$	"	$1\frac{3}{4}$
Stove,	"	$1\frac{3}{4}$	"	$1\frac{1}{4}$
Chestnut,	"	$1\frac{1}{4}$	"	$\frac{3}{4}$
Pea,	"	$\frac{3}{4}$	"	$\frac{1}{2}$
Buckwheat,	"	$\frac{1}{2}$	"	$\frac{1}{4}$

No specimen of broken coal was obtained, as this size is not prepared at Hauto, but is shipped directly from the breakers. There are two sizes larger than broken; steamboat coal, which, generally passes through a 7 and over a 4-inch mesh, and lump coal, which includes the largest pieces as they come from the mine. Specimens of these two larger sizes were not collected for examination, as the analyses already given in table No. I should represent the composition of these two sizes as they are shipped from the different breakers.

An inspection of table No. III shows a remarkable gradation in the ash and fixed carbon of the stove, chestnut, pea, and buckwheat coals. The difference in the ash between any one of these coals and the next larger or smaller sizes is about 2 per cent. This difference does not maintain, however, between the stove and egg coals, the former showing 4.5 per cent. more ash than the latter.

All of the analyses given in tables Nos. I and III show general averages; yet, it would not be fair to accept any one, as a standard of quality of the coal mined or shipped, from any special locality, in the Panther Creek basin, for any length of time.

The variability in the proportion of the different elements of the Panther Creek coals, shows the necessity of exercising the utmost care and judgment in sampling a coal for analysis; so that, in the case of a commercial product, the specimen shall represent an average.

4. Composition of the Ash of the Panther Creek Coals.

The economical utilization of ashes in large cities and in large industrial establishments will, no doubt, in the near future, become a very important question. Analyses were made of the combined ash of the two "Red Ash" coals (specimens 2 and 6), and of the seven "White Ash" coals, (specimens 1, 3, 4, 5, 7, 8, 9,) with the following results:

TABLE No. IV.—*Analyses of the Ashes obtained from the Red and White Ash Coals respectively in Table No. I.*

	Red Ash.		*White Ash.*	
Silica,	47.190		48.250	
Alumina,	32.522		36.177	
Sesquioxide of iron,	4 710		3.290	
Oxide of manganese,	trace.		trace.	
Lime,	3.640		1.950	
Magnesia,	.965		.921	
Sulphuric acid,	.712	=Sulphur, .285	.490	=Sulphur, .196
Phosphoric acid,	1.958	=Phosphorus, .855	.923	=Phospho's, .403
Titanic acid,	.990		.750	
Undetermined alkalies, &c.,	7.313		7.249	
	100.000		100.000	

5. Relation between the Composition of Coals and their Geological Structure.

As has been already stated (page 51), great difficulty was experienced in studying the structure of the Shaft anti-clinal and Lansford basins, in the vicinity of Nesquehoning tunnel No. 2 and Shaft No. 1; particularly, in the inside tunnel driven south from the gangway running west from the foot of the shaft. It was claimed, by those who had been connected with the mining in this locality, that the coal taken from the "*pocketed bed,*" in the tunnel south of the foot of Shaft No. 1 (See section No. 3, Cross section sheet

No. I), resembled the coal taken from the Mammoth (E) bed; that it burnt like it, and produced a similar ash.

The proper identification of the "*pocketed bed*," is a question of the greatest practical importance, and it was decided to make a careful chemical examination of the Nesquehoning coal beds, in order to obtain additional facts, which might help in the solution of the difficulty. If, as has been claimed, not only here, but in many other localities in the anthracite fields, different beds can be identified by their physical characteristics and the manner in which they burn, some similarity should exist in their chemical composition as well. While there are, undoubtedly, certain characteristics in the general appearance of coals, which will permit persons long familiar with certain coal beds to identify them within limited areas, I believe too much reliance has been placed upon this method, and that it has too frequently led to gross errors being committed.

Specimens of coal were collected at Nesquehoning and analyzed with two objects in view; (1) to obtain additional data for unravelling the local structure, and (2) to test in a general way, how far chemical analyses will aid in the identification of coal beds. Mr. Richard Eustice, Superintendent of the Nesquehoning mines, who has been familiar with the work done here for over twenty years, and who claimed with others that the character of the coal mined from the "*pocketed bed*" was distinctly that of the Mammoth bed, was instructed to collect duplicate specimens from the "*pocketed bed*," from the Mammoth bed near Shaft No. 1, and from the bed immediately below (north) the Mammoth bed near the mouth of Tunnel No. 1. These two latter beds were selected, as it has been generally conceded that the "*pocketed bed*" was either the Mammoth bed, or the one immediately below it. I desired Mr. Eustice to select the specimens, as I wished to make the test as thorough as possible, in ascertaining what assistance a long familiarity with certain beds would render in identifying them. Mr. Eustice is one of the most careful and intelligent observers of facts of any of the mine superintendents whom I have had the pleasure of meeting. I requested him to select the duplicate specimens *exactly alike*, as far as possible, and to have them represent the character of the coal which had been mined from each locality.

In addition to these duplicate specimens, others were collected, from the Mammoth bed in Tunnel No. 2; in the old workings of Slope No. 4; and of the Red Ash beds in Tunnel No. 2, and in the tunnel south from the foot of Shaft No. 1. These analyses are given in Table No. V. (See opposite page.)

A hurried glance, at the results in this table will show how absolutely impossible it would be, to argue from them any relationship between the different beds, from the fact that there are greater variations between the analyses of duplicate specimens, than between those of specimens collected from different beds. For instance, the analysis of specimen 1a resembles very much those of specimens 2a and 3; from these alone, the identity of the "*pocketed bed*" to the Mammoth might be argued. Such a conclusion, however, would hardly be justified when the analyses of specimens 1a, 2a and 4a are compared with those of their duplicates 1b, 2b, and 4b. Again if specimens 1b, 2a and 4b had alone been analysed it might have been concluded that the "*pocketed bed*" was the representative of the first bed below the Mammoth.

TABLE No. V.—*Analyses of the Coals mined at Nesquehoning Colliery No. 3.*

Specimen No.	Bed.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Color of ash.
1a	"Pocketed bed,"	2.590	3.883	86.233	0.851	6.443	100	Red with white specks.
1b	" "	2.440	3.998	80.301	0.649	12.612	100	" "
2a	Mammoth Shaft No. 1,	2.394	4.191	86.489	0.391	6.535	100	" "
2b	" " "	2.774	3.766	83.365	0.786	9.309	100	" "
3	Mammoth Slope No. 4,	3.796	3.749	86.214	0.343	5.898	100	Cream.
4a	Bed below Mammoth mouth of Tunnel No. 1,	3.558	3.707	83.741	0.435	8.559	100	Red with white specks.
4b	" " " " " " "	3.530	4.368	80.070	0.420	11.612	100	" "
5	North dip, F bed, Tunnel No. 2,	3.490	3.279	89.551	0.443	3.237	100	" "
6	South dip, F bed, Tunnel No. 2,	3.568	3.670	87.758	0.313	4.691	100	" "
7	1st bed in tunnel south of "Pocketed bed,"	2.324	7.619	81 335	0 542	8.180	100	Red.
8	2d bed in tunnel south of "Pocketed bed,"	2.348	3.960	88.525	0.547	4.620	100	Reddish-gray.

Chapter VIII.

1. Total Shipment and Production of Anthracite Coal in Penna.; 2. Anthracite Coal Tonnage of the different Transportation Companies; 3. Historical notes connected with the Development of the Anthracite Coal Fields.

1. Total Shipment and Production of Anthracite Coal in Pennsylvania.

No systematic collection of the statistics of the production of the anthracite mines will be made by the Geological Survey. They are at present collected and reported both by the mine inspectors and the Bureau of Industrial Statistics. While it might be desirable, that these statistics should be collected and regularly reported by the Survey, as it is done in England and by the United States Geological Survey for special mineral products, the law authorizing the State Geological Survey does not call for such returns, nor would the appropriation permit of such work being done by the Survey corps, without seriously embarrassing the regular geological work. The question as to how much coal still remains in the entire region, and in special tracts, is one so entirely dependent upon the geological structure of the coal basins that, in view of the increased production and ultimate exhaustion of the anthracite fields, it is necessarily one with which the Geological Survey has to deal.

The method adopted for computing the original coal contents is explained in the description of Miscellaneous sheet No. I.* In order to obtain the amount of coal still remaining to be mined, it is necessary to subtract from the total original contents, thus obtained, the amount of coal which has been mined. To do this, it becomes necessary for the Survey to estimate, from measurements of the thick-

* See chapter V.

nesses of the beds, and of the extent of territory which has been mined, the coal left in areas under development, and the amount of coal taken out of the mines, and to obtain such statistics of production as will show directly the aggregate amount of coal shipped from the mines.

Numerous demands have been made upon the Survey for estimates of the past production of the region; and it has seemed advisable, that some one of the many tables of production should be accepted, as the one to be used in all references to the subject in the Survey Reports. A number of tables have been examined with considerable care, and the one which has been adopted, by the Survey, is that compiled by Mr. P. W. Sheafer, of Pottsville, which shows the shipment of anthracite coal from 1820 to 1868. The statistics since 1868, which have been accepted, are those reported by Mr. John H. Jones, Confidential Accountant of the anthracite transporting companies. These are printed below, and have also been placed on Miscellaneous sheet No. III, in conjunction with a chart showing in a graphical way the growth of the production in the three regions of Schuylkill, Lehigh, and Wyoming, and in the entire State.

NOTE—The Loyalsock Coal Field in Sullivan county, which has now been embraced within the Anthracite Region, (see Report G^2), but whose production has not been included in the following table, has produced since 1870 as follows: 1871, 23,122; 1872, 51,527; 1873, 32,058; 1874, 36,268; 1875, 16,522; 1876, 30,000; 1877, 23,000; 1878, 37,000; 1879, 50,000; 1880, 50,000; 1881, 64,325; 1882, 77,198; total 491,020 tons.

TABLE No. I.—*Showing the Annual Shipment of Anthracite Coal in Pennsylvania since 1820, with the number of tons and percentage shipped from each region:**

Years.	Schuylkill Region.		Lehigh Region.		Wyoming Region.		Total Tons.
	Tonnage.	Per ct.	Tonnage.	Per ct.	Tonnage.	Per ct.	
1820, .	. . . . . .	. . .	365	. . .	. . . .	. . .	365
1821, .	. . . . . .	. . .	1,073	. . .	. . . .	. . .	1,073
1822, .	1,480	39.79	2,240	60.21	. . . .	. . .	3,720
1823, .	1,128	16.23	5,823	83.77	. . . .	. . .	6,951
1824, .	1,567	14.10	9,541	85.90	. . . .	. . .	11,108
1825, .	6,500	18 60	28,393	81.40	. . . .	. . .	34,893
1826, .	16,767	34.90	31,280	65.10	. . . .	. . .	48,047
1827, .	31,360	49.44	32,074	50.56	. . . .	. . .	63,434
1828, .	47,284	61.00	30,232	39.00	. . . .	. . .	77,516
1829, .	79,973	71.35	25,110	22.40	7,000	6.25	112,083
1830, .	89,984	51.50	41,750	23.90	43,000	24.60	174,734
1831, .	81,854	46.29	40,966	23.17	54,000	30.54	176,820
1832, .	209,271	57.61	70,000	19.27	84,000	23.12	363,271
1833, .	252,971	51.87	123,001	25.22	111,777	22.91	487,749
1834, .	226,692	60.19	106,244	28.21	43,700	11.60	376,636
1835, .	339,508	60.54	131,250	23.41	90,000	16.05	560,758
1836, .	432,045	63.16	148,211	21.66	103,861	15.18	684,117
1837, .	530,152	60 98	223,902	25.75	115,387	13.27	869,441
1838, .	446,875	60 49	213,615	28.92	78,207	10.59	738,697
1839, .	475,077	58.05	221,025	27.01	122,300	14.94	818,402
1840, .	490,596	56.75	225,313	26.07	148,470	17.18	864,379
1841, .	624,466	65.07	143,037	14.90	192,270	20.03	959,773
1842, .	583,273	52.62	272,540	24.59	252,599	22.79	1,108,412
1843, .	710,200	56.21	267,793	21.19	285,605	22.60	1,263,598
1844, .	887,937	54.45	377,002	23.12	365,911	22.43	1,630,850
1845, .	1,131,724	56.22	429,453	21.33	451,836	22.45	2,013,013
1846, .	1,308,500	55.82	517,116	22 07	518,389	22.11	2,344,005
1847, .	1,665,735	57.79	633,507	21.98	583,067	20.23	2,882,309
1848, .	1,733,721	56.12	670,321	21.70	685,196	22.18	3,089,238
1849, .	1,728,500	53.30	781,556	24.10	732,910	22.60	3,242,966
1850, .	1,840,620	54.80	690,456	20.56	827,823	24.64	3,358,899
1851, .	2,328,525	52.34	964,224	21.68	1,156,167	25.98	4,448,916
1852, .	2,636,835	52.81	1,072,136	21.47	1,284,500	25.72	4,993,471
1853, .	2,665,110	51.30	1,054,309	20.29	1,475,732	28.41	5,195,151
1854, .	3,191,670	53.14	1,207,186	20.13	1,603,478	26.73	6,002,334

*The Schuylkill region includes the Western Middle Field and that portion of the Southern Field west of Tamaqua. The Lehigh region includes the Eastern Middle Field and that portion of the Southern Field east of Tamaqua, known as the Panther Creek basin.

Anthracite Coal in Pennsylvania—Continued.

Years.	Schuylkill Region.		Lehigh Region.		Wyoming Region.		Total.
	Tonnage.	Per ct.	Tonnage.	Per ct.	Tonnage.	Per ct.	Tons.
1855, .	3,552,943	53 77	1,284,113	19.43	1,771,511	26.80	6,608,567
1856, .	3,603,029	52.91	1,351,970	19.52	1,972,581	28.47	6,927,580
1857, .	3,373,797	50.77	1,318,541	19.84	1,952,603	29.39	6,644,941
1858, .	3,273.245	47.86	1,380,030	20.18	2,186,094	31.96	6,839,369
1859, .	3,448.708	44.16	1,628,311	20.86	2,731,236	34.98	7,808,255
1860, .	3,749,632	44.04	1,821,674	21.40	2,941,817	34.56	8,513,123
1861, .	3,160,747	39.74	1,738,377	21.85	3,055,140	38.41	7,954,264
1862, .	3,372,583	42.86	1,351,054	17.17	3,145,770	39.97	7,869,407
1863, .	3,911,683	40.90	1,894,713	19.80	3,759,610	39.30	9,566,006
1864, .	4,161,970	40.89	2,054,669	20.19	3,960,836	38.92	10,177,475
1865, .	4,356,959	45.14	2,040,913	21.14	3,254,519	33.72	9,652,391
1866, .	5,787,902	45.56	2,179,364	17.15	4,736,616	37.29	12,703,882
1867, .	5,161,671	39.74	2,502,054	19.27	5,325,000	40.99	12,988,725
1868, .	5,330,737	38.62	2,502,582	18.13	5,968,146	43.25	13,801,465
1869, .	5,775,138	41.66	1,949,673	14.06	6,141,369	44.28	13,866,180
1870, .	4,968,157	30.70	3,239,374	20.02	7,974,660	49.28	16,182,191
1871, .	6,552,772	41.74	2,235,707	14.24	6,911,242	44.02	15,699,721
1872, .	6,694,890	34.03	3,873,339	19 70	9,101,549	46.27	19,669,778
1873, .	7,212,601	33.97	3,705,596	17.46	10,309,755	48.57	21,227,952
1874, .	6,866,877	34.09	3,773,836	18 73	9,504,408	47.18	20,145,121
1875, .	6,281,712	31.87	2,834,605	14.38	10,596,155	53.75	19,712,472
1876, .	6,221,934	33.63	3,854,919	20.84	8,424,158	45.53	18,501,011
1877, .	8,195.042	39.35	4,332,760	20.80	8,300,377	39 85	20,828,179
1878, .	6.282,226	35.68	3,237,449	18.40	8,085,587	45.92	17,605,262
1879, .	8,960,829	34.28	4,595,567	17.58	12,586,293	48.14	26,142,689
1880, .	7,554,742	32.23	4,463,221	19.05	11,419,279	48.72	23,437,242
1881, .	9,253,958	32.46	5,294,676	18 58	13,951,383	48.96	28,500,017
1882, .	9,459,288	32.48	5,689,437	19.54	13,971,371	47.98	29,120,096
Totals,	183,323,672	39.19	88,920,568	19.01	195,456,250	41.80	467,700,490

This table represents the total shipment of coal away from the region, and does not include the amount of coal consumed within the region. This amount has hitherto been variously estimated at from eight to ten per cent. of the total amount produced. Although the amount of coal burned within the coal-fields has increased from year to year, yet the percentage of the total amount mined, which has been so used, has unquestionably diminished at the same time. The total shipment, according to Messrs.

Sheafer and Jones, up to the end of 1881, has been 438,-580,394 tons, and if to this we should add nine per cent. for local consumption, the grand total would be 478,052,629 tons. During 1881 the mine inspectors gave this question careful consideration, and according to their estimates (See Chap. IX,) the amount consumed in the region during that year was about five and one half per cent. of the total amount produced.

The production reported by the mine inspectors for 1882 is 31,281,066 tons, so that the total output of the anthracite mines to January 1, 1883, has been 509,333,695 tons.*

It is hard to appreciate the enormous amount of anthracite which has already been mined. Assuming that a ton of coal, of 2,240 pounds in the bed, contains 25 cubic feet; 509,333,695 tons would form a solid wall 100 feet wide and 100 feet high for a distance of about 241† miles; or it would form a solid wall along the line of the Pennsylvania Railroad, between Philadelphia and New York, 100 feet wide and over 268 feet high.

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2. Anthracite Coal Tonnage of the different Transportation Companies.

Since 1870 Mr. Jones has kept a careful record of the coal tonnage of the different railroad and canal companies which have transported anthracite coal from the region. It is shown in the following table:

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*This does not include the production of the Loyalsock field.

† If a similar estimate be made with the coal in broken sizes, as it has been shipped to market, on a basis of 40 cubic feet to a ton, a wall would be formed 100 feet wide and 100 feet high for a distance of 386 miles, which is very nearly the distance from Trenton, New Jersey, to Pittsburgh, along the line of the Pennsylvania Railroad.

TABLE NO. II.—*Anthracite Coal Tonnage of the different Transportation Companies, compiled upon the Basis of Distribution established by the Anthracite Board of Control for 1878. Reported by Mr. John H. Jones, Confidential Accountant.*

TRANSPORTING COMPANIES.	1870.	1871.	1872.	1873.	1874.	1875.
Philadelphia and Reading Railroad Company,	4,169,707	5,330,863	5,645,103	5,868,848	5,568,601	4,782,311
Lehigh Valley Railroad Company,	3,608,587	2,880,263	3,850,118	4,121,734	3,989,821	3,285,225
Central Railroad Company of New Jersey,	1,606,469	1,985,550	2,253,614	2,698,119	2,706,007	2,465,902
Delaware, Lackawanna & Western Railroad Company,	2,117,612	1,730,242	2,520,330	2,952,941	2,353,539	2,833,670
Delaware and Hudson Canal Company,	2,318,073	1,955,737	2,882,479	2,732,267	2,290,791	2,843,229
Pennsylvania Railroad Company,	1,225,733	912,835	1,168,084	1,519,711	1,642,474	1,772,719
Pennsylvania Coal Company,	1,136,010	848,635	1,266,762	1,297,604	1,396,326	1,426,377
New York, Lake Erie and Western Railroad,		55,596	83,288	36,728	197,562	303,039
Total,	16,182,191	15,699,721	19,669,778	21,227,952	20,145,121	19,712,472

TRANSPORTING COMPANIES.	1876.	1877.	1878.	1879.	1880.	1881.	1882.
Philadelphia and Reading Railroad Co.,	4,931,754	6,842,105	5,112,219	7,442,617	5,933,923	6,940,283	7,000,113
Lehigh Valley Railroad Company,	3,985,351	4,447,881	3,403,318	4,405,958	4,394,533	5,721,870	5,933,740
Central Railroad Company of New Jersey,	2,778,096	2,837,500	2,264,979	3,825,553	3,470,141	4,085,424	4,211,052
Delaware, Lackawanna & Western R. R. Co.,	1,998,654	2,089,523	2,180,673	3,867,405	3,550,348	4,388,970	4,638,717
Delaware and Hudson Canal Company,	1,809,190	1,787,470	2,046,235	3,014,117	2,674,705	3,211,496	3,203,168
Pennsylvania Railroad Company,	1,623,335	1,530,594	1,362,674	1,682,106	1,864,032	2,211,363	2,332,974
Pennsylvania Coal Company.	1,143,922	1,118,011	957,032	1,427,150	1,138,466	1,475,380	1,469,821
New York, Lake Erie & Western Railroad,	230,709	175,095	278,132	477,783	411,094	465,230	330,511
Total,	18,501,011	20,828,179	17,605,262	26,142,689	23,437,242	28,500,016	29,120,096

3. Historical Notes connected with the Development of the Anthracite Coal Fields.

The following historical notes connected with the development of the region, and the mining of coal, have been compiled and published in conjunction with the statistics of production. A complete history of the development of the Anthracite Coal Fields will be published with the final geological report:

1820. Lehigh Coal and Navigation Company began mining and shipping coal from Summit Hill region. Canal opened, Mauch Chunk to Easton, 1829. White Haven to Mauch Chunk, 1837.

1825. Schuylkill Canal was completed from Mt. Carbon to Philadelphia.

1829. Delaware & Hudson Canal Co. began transporting coal from Carbondale region.

1831. Nesquehoning R. R. and Plane built.

1831. Morris Canal opened, Phillipsburg to Newark; opened to Jersey City, 1836. Leased by Lehigh Valley R. R. Co., 1872.

1832. Little Schuylkill R. R. began transporting coal from Tamaqua region.

1832. Shamokin Division, Northern Central Railway, originally opened. Reorganized 1851. Leased to Northern Central Railway, 1863.

1833. Delaware Division Pennsylvania Canal opened.

1834. Wyoming and State Canals opened.

1835. First Geological Survey of the Anthracite Coal Fields commenced.

1837. Shipments of coal began from Beaver Meadow region.

1837. Shipments of coal began from Pine Grove, via Union Canal.

1837. Morris & Essex R. R. opened. Leased to D., L. & W. R. R. Co., 1869.

1838. Shipments of coal began from Hazleton region.

1839. Summit Branch R. R. opened. Leased to S. B. R. R. Co., 1866.

1839. Shipments of coal began from Shamokin region westward.
1839. Shipments of coal began from Lykens Valley region westward.
1840. Shipments of coal began from Buck Mountain region.
1840. Quakake R. R. opened. Extended and opened to Mt. Carmel 1862.
1841. First Geological Survey of the Anthracite Coal Fields completed.
1842. Philadelphia & Reading R. R. began transporting coal through to Pt. Richmond.
1846. Shipments of coal began from Wilkes Barre region, via L. & S. R. R. Planes, and Lehigh Canal.
1850. Pennsylvania Coal Company began business.
1852. Central R. R. of N. J. opened from Elizabeth to Easton. Third rail from Hampton Junc. laid 1856.
1854. Delaware, Lackawanna & Western R. R. Co. began mining and shipping coal.
1855. Lehigh Valley R. R. Co. began transporting coal to Phillipsburg. Opened to Perth Amboy in 1875.
1856. Trevorton R. R. opened.
1857. Belvidere & Delaware R. R. began transporting coal.
1857. North Pennsylvania R. R. opened. Leased to Philadelphia & Reading R. R. Co. May 1, 1879.
1858. Lackawanna & Bloomsburg R. R. opened. Leased to D., L. & W. R. R. Co., 1873.
1858. Mining began in McCauley Mountain region.
1868. Lehigh & Susquehanna R. R. opened to Phillipsburg. Leased to C. R. R. of N. J., 1871.
1869. Pennsylvania & New York R. R. opened to Waverly.
1870. Nesquehoning Valley R. R. and Tunnel into Panther Creek basin opened.
1870. Sunbury, Hazleton & Wilkes Barre R. R. opened. Leased by Pennsylvania R. R., 1878.
1871. Erie Railway Co. began mining and shipping coal.
1873. Philadelphia & Reading Coal and Iron Co. began mining and shipping coal.
1874. Lehigh & Wilkes Barre Coal Co. began operations.

1879. Philadelphia & Reading R. R. Co. leased Delaware & Bound Brook R. R., May 1.

1880. Second Geological Survey (reconnaissance) of the Anthracite Coal Fields commenced, August.

1881. Second Geological Survey of the Anthracite Coal Fields regularly organized and commenced, under plan approved by the State Geologist and Board of Commissioners, July.

1883. Philadelphia and Reading R. R. leased Central R. R. of New Jersey and leased lines, May 29th.

1883. First shipment made over Shamokin, Sunbury & Lewisburg and Jersey Shore and Pine Creek R. R's. from Merriam Colliery ($31\frac{12}{20}$ tons egg coal) to S. M. Devoy & Co., Syracuse, N. Y., June 28th.

These notes are by no means complete; they only contain a record of the more prominent facts, connected with the development of Pennsylvania anthracite.

CHAPTER IX.

1. Description of Map, Sections and Statistics on Miscellaneous Sheet No. II; 2. List of Operating Collieries with their Total Production 1881 and 1882; 3. Total Production and Shipment from Mine Inspectors' Districts 1881 and 1882; 4. Total Production of Counties for 1882; 5. Columnar Sections showing the Average Thickness of the Coal Measures in the different Anthracite Fields; 6. Northern Field; 7. Eastern Middle Field; 8. Western Middle Field; 9. Southern Field; 10. Difficulties of Identification.

1. Description of Map, Sections and Statistics on Miscellaneous Sheet No. II.

The information published on this sheet is of a very general character, not exact as might be wished; it was compiled, however, to meet a demand for a small connected map of the coal fields to show the geographical positions of the basins; the location of the collieries and their relative size by the number of tons produced during the years 1881 and 1882; and finally the thickness of the coal measures, and particularly the number and thickness of the coal beds in the different districts, with an indication as to the identification of the different coal beds throughout the region. The progress of the Geological Survey has not been sufficient, to enable it to construct an original map of all the coal fields; to compile a complete list of the working collieries; or to make a final statement as to the thickness of the coal rocks, the number and thickness of coal beds, or to propose a comparison of the beds in the different districts.

As to how far these inquiries can be answered, at the present time, is attested by this sheet, which contains the most reliable information available on the subject.

The map* was compiled from the following:

Walling and Gray's County Atlas and Wall Map of Pennsylvania,

Sturdevant's map of Luzerne County,

Township atlases of Carbon and Schuylkill Counties,

Geological maps of Wyoming and Sullivan Counties, Report G^2, and

Sketch map to illustrate report on coal lands of the Philadelphia and Reading Coal and Iron Company, by Mr. Joseph S. Harris.

The errors which will be found on this map, by persons familiar with special areas in this part of the State, will show the necessity for a more accurate representation. The original maps drawn on a large scale, which have been contributed for the use of the Geological Survey, and those which have already been constructed from the surveys of the Survey corps, are being reduced on to a connected map, drawn to a scale of one mile to one inch. It is proposed to publish this map, on a scale of two miles to one inch, with the final report, after the survey of the entire region is completed.

The division of the coal basins into districts, is that which has been arbitrarily accepted by the coal trade, and which has been used for several years by Mr. John H. Jones in the compilation of his annual list of collieries. These divisions have been provisionally adopted by the Survey for convenience of description.

The list of working collieries, on Miscellaneous sheet No. II, with their production, has been compiled from the mine inspectors' reports for the year 1881. Some of the collieries given in the reports are not contained in Mr. Jones' list and *vice versa*, so that in some cases considerable difficulty was experienced in deciding under which division of Mr. Jones' list the collieries in the reports, which were not found in his list, should be placed.†

The number of working collieries is constantly changing,

* Drawn by Charles B. Scott. † See page 199.

on account of old mines being closed and new ones being opened. The production, of some of those which are kept working, changes from year to year; so that, a list which may be complete for one year, imperfectly represents the mining operations for the next. For general reference, however, the list on this sheet is of great value, and it has been reprinted here as being more convenient for ready reference, together with a similar list for 1882, compiled from advance sheets of the mine inspectors' reports for that year.

The tonnage reported in the table is, in some cases, the shipment, while in others it is the production, which includes the shipment from the colliery, and that which is used at the colliery for fuel and sold to the local trade. No uniform plan has been employed by all the mine inspectors in reporting the shipment and production of the anthracite collieries. (See page 216.)

For more detailed information the reader is directed to the "Reports of the Inspectors of Mines of the Anthracite Coal Region" for 1881 and 1882.

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† This is only an apparent discrepancy. The collieries enumerated in Mr. Jones' list indicate the points from where the shipments are made and the shipping reports are returned; whereas, the collieries in the mine inspectors list are really the working mines, a number of which, in many cases, ship their product from the same point.

2. TABLE NO. I.—*List of Operating Collieries, with their Total Production 1881 and 1882.*

1. Carbondale District.

No. of Inspect's. dist.	NAME OF COLLIERY, 1882.	Location.	Operator 1882.	Tons. 1881.	Tons. 1882.
5	Filer Nos. 1 & 2,	Winton borough,	Filer & Levy,	132,720	87,418
5	Pierce,	Archbald,	John Hosic & Son,	130,000	129,706
5	Eaton,	"	Jones, Simpson & Co.,	108,193	102,911
5	Jermyn, No. 1 Shaft,	Jermyn,	Del. & Hudson Canal Co.,	118,481	115,953
5	Jermyn Slope,	"	" "	34,480	57,701
5	Erie,	Glenwood,	Hillside Coal & Iron Co.,	79,411	92,437
5	Keystone Tunnel,	"	" "	..	663
5	Belmont,	Carbondale,	Cowan & Daning,	4,856	56,671
5	Elk Creek,	Fell township,	Brennan & Bridget,	17,838	*788
5	Forest City,	Clifford township,	Susquehanna Coal Co., Hillside Coal & Iron Co.,	19,856	14,465
5	Olyphant No. 2,	Olyphant borough,	Del. & Hudson Canal Co.,	105,239	93,264
5	Grassy Island,	" "	" "	142,282	119,612
5	White Oak,	Archbald,	" "	123,480	109,132
5	Carbondale, No. 1 Shaft,	Carbondale,	" "	25,923	33,631
5	Carbondale, No. 3 Shaft,	"	" "	6,182	4,572
5	Coal Brook,	"	" "	220,639	187,900
5	Racket Brook,	Carbondale township,	" "	175,339	157,225
				1,444,919	1,364,049

* Burned.

2. *Scranton District.*

5	National,	Lackawanna township,	Wm. Connell & Co.,	124,004	121,682
5	Meadow Brook,	Scranton, 20th ward,	" "	116,431	123,979
5	Bridge,	" 14th "	Bridge Coal Co.,	56,700	68,585
5	Mount Pleasant,	" 14th "	Wm. T. Smith,	123,716	126,926
5	Capouse,	" 21st "	Lackawanna I. & C. Co.	276,840	326,340
5	Pine Brook,	" 7th "	" "	13,481	14,223
5	Fairlawn,	" 7th "	Fairlawn Coal Co.,	53,056	38,633
5	Jermyn's, No. 3, / Jermyn's Green Ridge, / Jermyn, No. 3 shaft,	" 13th "	Del. Lack. & West'n R. R. Co.* and Del., & Hudson Canal Co.,	181,514	91,500 / 91,158
5	Green Ridge,	Dunmore,	O. S. Johnson & Co.,	186,831	151,511
5	Roaring Brook,	"	Edward Spencer & Son,	90,000	Local sales.
5	Elk Hill,	Dickson City borough,	Elk Hill Coal and Iron Co.,	50,107	55,963
5	Shaft No. 2, Dunmore,	Dunmore,	Penn'a. Coal Co.,	53,407	55,701
5	Gypsy Grove Shafts, Nos. 3 & 4,	"	" "	113,596	117,662
5	Pyne,	Lackawanna township,	Del., Lack. & West'n. R. R. Co.,	167,667	181,082
5	Taylor,	" "	" "	149,358	153,846
5	Archbald,	" "	" "	79,565	99,638
5	Sloan,	" "	" "	119,126	100,243
5	Continental,	" "	" "	48,213	149,878
5	Hampton,	" "	" "	190,471	172,282
5	Bellevue,	" "	" "	165,486	160,729
5	Scranton Slope,	" "	" "		36,193
5	Dodge,	" "	" "	140,917	137,515
5	Central,	Scranton, 15th ward,	" "	138,769	172,110
5	Hyde Park,	" 5th "	" "	142,670	118,950
5	Diamond Shaft, No. 2,	" 21st "	" "	181,224	152,974
5	Diamond Slope, No. 2,	" 21st "	" "	81,401	71,013
5	Diamond Tripp Slope,	" 21st "	" "	69,017	67,948
5	Brisbin,	" 21st "	" "	145,251	122,374
5	Cayuga,	" 3d "	" "	107,014	109,923
5	Von Storch,	" 2d "	Del. & Hudson Canal Co.,	237,756	231,595

*Jermyn's Green Ridge in the list for 1881 (see Miscellaneous sheet No. II) is the same as Jermyn No. 3 and Jermyn No. 3 shaft in the present list. This colliery was worked in 1882 during alternate months by the companies named.

3. *Scranton District—Continued.*

No. of Inspect's. dist.	NAME OF COLLIERY, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
5	Leggitt's Creek,	Scranton, 1st "	Del. & Hudson Canal Co.,	137,289	154,398
5	Marvin,	" 1st "	" "	165,628	149,522
5	Lucas,	" 2d "	Lucas Coal Co.,	. . . . . .	1,500
5	Pancoast Shaft and Slope,	Dickson City borough,	Pancoast Coal Co.,	. . . . . .	63,707
5	Throop or Jermyn, No. 4,	" "	John Jermyn,	. . . . . .	8,390
				3,846,505	3,999,673

3. *Pittston District.*

No. of Inspect's. dist.	NAME OF COLLIERY, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
5	Everhart,	Jenkins township,	Waddell & Co.,	56,861	44,954
5	Tompkins,	Pittston borough,	G. R. Wilson & Co.,	13,882	1,500
5	Fairmount,	" township,	A. Morris & Co.,	53,878	57,986
5	Twin,	" borough,	Pittston Coal Co.,	33,546	49,500
5	*Seneca,	" "	" "	54,270	21,973
5	Beaver,	" "	Waterman & Beaver,	16,029	19,587
5	Butler,	Pittston township,	Butler Coal Co.,	63,326	56,000
5	Mosier,	Hughestown,	" "	52,200	67,985
5	Heidelberg, (Shaft,)	Pittston township,	Lehigh Valley Coal Co.,	2,000	55,500
5	Phœnix,	Marcy township,	Phœnix Coal Co.,	36,112	31,417
5	Hillside,	Pleasant Valley,	Hillside Coal and Iron Co.,	62,624	58,031
5	Columbia,	Marcy township,	Grove Brothers,	15,605	25,825
5	Slope No. 2,	Jenkins township,	Pennsylvania Coal Co.,	49,504	49,435

*Abandoned July 1, 1882.

3. Pittston District—Continued.

5	Slope No. 4,	Jenkins township,	Pennsylvania Coal Co.,	71,962	66,155
5	Shaft No. 5,	" "	" "	71,270	70,776
5	Shaft No. 6,	" "	" "	56,874	57,930
5	Shaft No. 7,	" "	" "	94,625	77,840
5	Shaft No. 11,	" "	" "	36,280	29,530
5	Shaft No. 4,	" "	" "	90,515	77,771
5	Shaft No. 1,	Hughestown borough.	" "	29,477	31,163
5	Shaft No. 8,	" "	" "	60,686	66,855
5	Tunnel No. 1,	Pittston township,	" "	40,878	39,008
5	Slope No. 6,	Hughestown borough,	" "	27,826	28,056
5	Shaft No. 9,	Pittston,	" "	69,323	81,712
5	Shaft No. 10,	Hughestown,	" "	126,130	125,106
5	Shaft No. 12,	Pleasant Valley,	" "	76,975	56,805
5	Shaft No. 13,	Old Forge township,	" "	24,135	16,113
5	Barnum No. 1,	Marcy township,	" "	173,287	169,231
5	Barnum No. 2,	" "	" "	. .	81,178
5	Law,	Pittston township,	" "	68,801	58,733
5	Stark,	Lackawanna township,	" "	73,263	76,521
5	Greenwood,	" "	Pennsylvania Anthracite Co.,	149,013	140,023
5	Sibley,	Old Forge township,	" "	76,871	76,420
5	Spring Brook,	Moosic, Lackawanna twp.,	Hillside Coal and Iron Co.,	90,590	69,700
5	Eagle,	Pittston borough,	Northern Coal Co.,	. . . . . .	4,219
5	Stetler,	Marcy township,	S. N. Stetler & Co.,	. . . . . .	35,125
4	Exeter,	West Pittston,	Lehigh Valley Coal Co.,	209,000	111,500
				2,227,618	2,187,163

4. Wilkes Barre District.

4	Prospect,	Plainsville,	Lehigh Valley C. Co.,	224,227	223,633
4	Mineral Spring,	"	" "	79,930	80,467
4	Midvale,	"	" "	55,808	52,256

4. *Wilkes Barre District—Continued.*

No. of Inspector's dis.	NAME OF COLLIERY, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
4	Henry,	Plainsville,	Lehigh Valley C. Co.,	122,937	123,411
4	Diamond,	Wilkes Barre,	Lehigh & Wilkes Barre C. Co.,	179,216	100,645
4	Hollenback,	"	" "	238,051	227,929
4	Empire,	"	" "	308,282	268,178
4	Hartford,	Ashley,	" "	213,155	216,762
4	Sugar Notch (No. 9) Shaft,	Sugar Notch,	" "	166,802	162,976
4	Sugar Notch (No. 10) Slope,	"	" "	134,388	87,802
4	Nottingham,	Plymouth,	" "	371,198	334,921
4	Reynolds,	"	" "	162,173	160,249
4	Wanamie,	Wanamie,	" "	121,377	133,661
4	Mill Creek,	Mill Creek,	Del. & Hudson Canal Co.,	165,283	172,350
4	Pine Ridge,	Plainsville,	" "	135,612	126,423
4	Laurel Run,	"	" "	164,174	140,718
4	Baltimore Slope,	Wilkes Barre,	" "	102,990	99,042
4	Baltimore Tunnel,	"	" "	144,485	79,940
4	Conyngham,	"	" "	38,775	108,886
4	Plymouth No. 2,	Plymouth,	" "	124,277	213,444
4	Plymouth No. 3,	"	" "	199,811	158,669
4	Plymouth No. 4,	"	" "	101,287	113,342
4	Plymouth No. 5,	"	" "	204,415	189,386
4	Breaker No. 1,	Nanticoke,	Susquehanna C. Co.,	. . .	155,276
4	Breaker No. 2,	"	" "	766,750	329,611
4	Breaker No. 5,	"	" "	. . .	302,213
4	Breaker No. 3 or Grand Tunnel,	"	" "	85,927	117,067
4	Avondale,	Plymouth,	Del., Lack'a & West'n R. R. Co.,	168,989	187,119
4	Boston,	"	" "	105,561	94,341
4	Warrior Run,	Warrior Run,	A. J. Davis.	60,000	51,811
4	No. 1 Kingston,	Kingston,	Kingston Coal Co.,	141,199	183,103
4	No 2 Kingston,	"	" "	252,887	250,106

4	Gaylord,	Plymouth,	Gaylord Coal Co.,	163,010	168,804
4	Franklin,	Wilkes Barre,	Franklin Coal Co.,	145,229	160,306
4	Wyoming,	Plainsville,	Wyoming Valley C. Co.,	214,475	222,646
4	Forty-Fort,	Forty-Fort,	" "	112,331	120,477
4	Enterprise,	Plainsville,	Andrew Langdon & Co.,	137,930	145,456
4	East Boston,	Kingston,	W. G. Payne & Co.,	112,000	115,000
4	Black Diamond,	"	Haddock & Steele,	84,783	82,946
4	Maltby,	"	C. S. Maltby,	98,538	30,552
4	Harry E,	"	Wyoming Valley C. Co.,	12,831	54,527
4	Red Ash No. 1,	Wilkes Barre,	Red Ash Coal Co.,	92,599	97,454
4	Red Ash No. 2,	'	" "	. . . . .	69,204
4	Raubville,	Kingston,	Waddell & Walter,	40,770	64,100
4	Dodson,	Plymouth,	Plymouth Coal Co.,	98,648	121,477
4	Salem,	Shickshinny,	Salem Coal Co.,	52,450	47,450
4	Hillman,	Plainsville,	H. Baker Hillman,	52,000	50,000
4	Chauncey,	Plymouth,	T. P. MacFarlane,	24,515	23,593
4	R. S. Poole,	Wilkes Barre,	R. S. Poole,	19,450	13,182
4	Mocanaqua,	Hartville,	West End Coal Co.,	10,980	88,711
4	Bennett,	Mill Creek,	Thos. Waddell & Co.,	. . . . . .	26,226
				6,812,505	6,947,848

5. Green Mountain Basin.

6	Pond Creek,	Pond Creek,	Pond Creek Coal Co.,	32,822	
6	Upper Lehigh Nos. 1, 2, & 3,	Upper Lehigh,	Upper Lehigh Coal Co.,	217,909	198,579
6	Upper Lehigh No. 4,	"	" "	169,833	166,601
				420,564	365,180

6. Black Creek Basin.

6	Sandy Run,	Sandy Run,	M. S. Kemmerer & Co.,	136,085	181,759
6	Highland No. 1,	Highland,	G. B. Markle & Co.,	99,009	104,358
6	Highland No. 2,	"	" "	98,866	124,472

6. Black Creek Basin.—Continued.

No. of Inspect's. dist.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
6	Oakdale No. 1,	Jeddo,	G. B. Markle & Co.,	111,433	117,205
6	Oakdale No. 2,	"	" "	104,512	126,600
6	Council Ridge No. 2,	Eckley,	J. Leisenring & Co.,	155,572	176,795
6	Council Ridge No. 5,	"	" "	98,979	160,632
6	Cross Creek No. 1,	Drifton,	Coxe Bros. & Co.,	214,629	223,929
6	Cross Creek No. 2,	"	" "	266,734	237,998
6	Cross Creek No. 3,	"	" "	15,891	30,373
6	West Cross Creek No. 1,	Gowen,	" "	37,510	55,229
6	Ebervale Nos. 1 & 2,	Ebervale,	Ebervale Coal Co.,	122,266	147,105
6	Ebervale Nos. 3, 5, & 6,	"	" "	76,559	110,278
6	Black Ridge,	Conyngham,	Black Ridge Coal Co.,	21,754	63,694
6	Hollywood,	Hollywood,	Calvin Pardee & Co.,	125,141	125,841
6	Lattimer No. 1,	Lattimer,	Pardee Bros. & Co.,	124,755	112,179
6	Lattimer No. 2,	"	" "	129,999	126,853
6	Milnesville No. 6,	Milnesville,	Stout Coal Co.,	87,381	39,750
6	Milnesville No. 7,	"	" "	55,024	81,043
6	Harleigh,	Harleigh,	McNair & Co.,	94,755	88,667
				2,176,854	2,434,760

7. Hazleton Basin.

No. of Inspect's. dist.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
6	Hazleton,	Hazleton,	Ario Pardee & Co.,	77,059	92,106
6	Laurel Hill,	"	" "	138,440	91,556
6	Hazleton No. 3,	"	" "	32,289	57,081

6	Hazleton No. 6,	Hazleton,	Ario Pardee & Co.,	154,072	156,237
6	Cranberry,	"	" "	124,153	121,888
6	East Crystal Ridge,	"	" "	61,382	56,088
6	Sugar Loaf,	"	" "	53,121	44,252
6	South Sugar Loaf,	Hazleton,	Ario Pardee & Co.,	45,916	54,519
6	East Sugar Loaf No. 1,	Stockton,	Linderman, Skeer & Co.,	. .	62,363
6	East Sugar Loaf No. 4,	"	" "	102,413	
6	East Sugar Loaf No. 5,	"	" "	. .	131,027
6	East Sugar Loaf No. 2,	"	" "	37,499	64,606
6	East Sugar Loaf No. 3,	"	" "	89,583	83,851
6	Buck Mountain,	Buck Mountain,	Buck Mountain Coal Co.,	120,719	108,906
6	Mount Pleasant,	Mount Pleasant,	Pardee Sons & Co.,	146,691	143,373
6	Humboldt,	Humboldt,	Linderman, Skeer & Co.,	96,240	87,730
				1,279,577	1,355,583

8. *Beaver Meadow Basin.*

6	Coleraine,	Beaver Meadow,	Wm. T. Carter & Co.,	138,187	153,360
6	Spring Mtn. No. 1,	Jeansville,	J. C. Haydon & Co.,	102,075	
6	Spring Mtn. No. 4,	"	" "	. . . . .	119,568
6	Spring Mtn. No. 5 and Drift,	"	" "	113,025	
6	Spring Mtn. No. 7,	"	" "	. . .	122,811
6	Tresckow,	Tresckow,	E. B. Leisenring & Co.,	116,561	135,605
6	Spring Brook No. 5,	Yorktown,	Geo. H. Myers & Co.,	83,685	86,400
6	Spring Brook No. 6,	"	" "	94,994	98,674
6	Beaver Brook,	Frenchtown,	C. M. Dodson & Co.,	98,028	99,367
2	Honeybrook No. 1,	Audenried,	Lehigh & Wilkes Barre C. Co.,	81,116	51,381
2	Honeybrook No. 4,	"	" "	164,940	163,580
2	Honeybrook No. 5,	"	" "	124,302	108,419
				1,116,913	1,139,165

9. *East Mahanoy District.*

2	Ellangowan,	Lanigans,	Phila. & Read. Coal & Iron Co.,	240,977	244,121
2	Elmwood,	Mahanoy City,	" "	282	20,841

9. *East Mahanoy District—Continued.*

No. of Inspector's dis.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
2	Knickerbocker,	Yatesville,	Phila. & Read. Coal & Iron Co.,	113,555	92,168
2	Mahanoy City,	Mahanoy City,	" "	114,339	113,340
2	North Mahanoy,	"	" "	71,190	52,710
2	Schuylkill,	"	" "	81,925	83,973
2	St. Nicholas,	St. Nicholas,	" "	111,031	106,400
2	Tunnel Ridge,	Mahanoy City,	" "	74,654	70,008
2	Coplay,	"	L. F. Lentz,	68,777	75,958
2	Glendon,	"	J. C. Haydon & Co.,	95,481	111,436
2	Primrose,	"	Primrose Coal Co.,	55,193	56,460
2	Coal Run,	St. Nicholas,	Suffolk Coal Co.,	127,400	136,192
2	Staffordshire,	" "	Jones & Oliver,	11,422	7,881
2	West Lehigh,	Mahanoy City,	Fisher Hazzard,	46,757	47,666
2	Webster,	"	L. S. Baldwin,	24,119	25,381
2	North Star,	"	Reynolds & Roberts,	24,000	8,466
				1,261,102	1,253,001

10. *West Mahanoy District.*

2	Boston Run,	Boston Run,	Phila. & Read. Coal & Iron Co.,	46,705	80,470
2	Conner,	Girardville,	" "	137,251	138,294
2	Girard,	"	" "	69,567	104,647
2	Hammond,	"	" "	95,274	93,839
2	Indian Ridge,	Shenandoah,	" "	143,562	144,602
2	Plank Ridge.	"	" "	107,195	108,258
2	West Shenandoah,	"	" "	122,264	103,777

2	Shenandoah City,	Shenandoah,	Phila. & Read. Coal & Iron Co.,	84,819	116,213
2	Bear Run,	St. Nicholas,	" "	19,221	43,751
2	Gilberton,	Gilberton,	" "	52,988	77,090
2	Girard Mammoth,	Raven Run,	" "	14,273	47,833
2	Turkey Run,	Shenandoah,	" "	114,298	127,764
2	Bear Ridge No. 1,	Mahanoy Plane,	Myers, McCreary & Co.,	63,196	69,284
2	Bear Ridge No. 2,	"	" "	74,425	65,491
2	Packer No. 1,	West Mahanoy township,	Lehigh Valley Coal Co.,	81,564	61,700
2	Packer No. 2,	" "	" "	126,510	98,434
2	Packer No. 3,	" "	" "	170,078	158,595
2	Packer No. 4,	" "	" "	200,682	218,128
2	Cambridge,	Shenandoah,	Cambridge Coal Co.,	9,065	10,939
2	Cuyler,	Raven Run,	S. M. Heaton & Co.,	177,954	175,949
2	Draper,	Gilberton,	Draper Coal Co.,	117,132	114,632
2	Kohinoor,	Shenandoah,	R. Heckscher & Co.,	175,861	162,000
2	Lawrence,	Mahanoy Plane,	Jacob S. Lawrence,	112,200	95,368
2	Stanton,	Maizeville,	Miller, Hoch & Co.,	57,854	68,733
2	Kehley's Run,	Shenandoah,	Thomas Coal Company,		79,616
2	William Penn,	West Mahanoy township,	William Penn Coal Co.,	222,252	228,000
2	Laurel Ridge,	Mahanoy City,	John A. Dutter,	11,016	24,104
2	Oakdale,	Shenandoah,	E. L. Powell,	10,000	10,000
3	Mt. Carmel Shaft,	Mt. Carmel,	Phila. & Read. Coal & Iron Co.,	184,358	182,139
3	Bast,	Big Mine Run,	" "	91,785	90,161
3	Keystone,	Locust Dale,	" "	7,726	2,709
3	Merriam,	Locust Summit,	" "	93,589	116,772
3	Potts,	Locust Dale,	" "	96,240	83,941
3	North Ashland,	Dark Corner,	" "	119,300	111,036
3	Preston Nos. 1 and 2,	Girardville,	" "	63,491	68,029
3	Preston No. 3,	"	" "	88,576	86,079
3	Tunnel,	Ashland,	" "	17,404	49,095
3	North Franklin,	Trevorton,	" "	93,310	86,382
3	Reliance,	Mt. Carmel,	" "	104,964	118,841
3	Locust Spring,	Locust Gap,	" "	90,508	95,448
3	Locust Gap,	"	Greaber & Shepp,	86,000	73,205
3	Ben Franklin,	Doutyville,	Baumgartner & Douty,	32,158	31,007
3	Monitor,	Locust Gap,	George W. Johns & Bro.,	126,062	131,546
3	Black Diamond,	Mt. Carmel,	William Schwenk & Co.,	7,368	21,329
3	Hazel Dell,	Centralia,	L. A. Riley & Co.,	29,000	7,638
3	Mt. Carmel,	Mt. Carmel,	Montelius, Righter & Co.,	135,612	170,643

10. *West Mahanoy District—Continued.*

No. of Inspect'rs dist.	Name of Colliery 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
3	Big Mine Run,	Big Mine Run,	Jeremiah Taylor & Co.,	134,525	132,362
3	Continental,	Centralia,	Lehigh Valley Coal Co.,	62,506	16,542
3	Montana No. 1,	"	Daniel Beaver,	73	abandoned.
3	Gordon,	Barry township,	William Cleaver & Co.,	29,917	23,368
3	Rausch Gap,	Valley View,	W. H. Yoke,	1,195	1,088
3	Monroe,	Montana,	A. H. Church,	42,941	35,854
3	Pioneer,	Ashland,	David Vaughn & Co.,	958	440
3	Logan,	Centralia,	Lewis A. Riley & Co.,	117,525	231,169
3	Centralia,	"	" "	10,662	88,283
3	Bear City,	"	John Q. Williams,	2,450	2,000
3	Morris Ridge,	"	Isaac May & Co.,	45,507	55,490
3	Bellmore,	Mt. Carmel,	S. S. Bickle & Co.,	. . . . .	6,806
				4,532,916	4,946,913

11. *Shamokin District.*

No. of Inspect'rs dist.	Name of Colliery 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
3	Bear Valley,	Shamokin,	Phila. & Read. Coal & Iron Co.,	73,174	69,634
3	Burnside,	Carbon Run,	" "	50,918	68,048
3	Big Mountain,	Shamokin,	Patterson & Llewellyn,	178,959	168,770
3	Excelsior,	Excelsior,	Excelsior Coal Co.,	142,481	125,464
3	Enterprise,	"	Enterprise Coal Co.,	141,820	121,020
3	Henry Clay,	Shamokin,	J. Langdon & Co.,	114,935	91,675
3	Peerless,	"	Cruikshank & Ennis,	46,016	47,825
3	Sterling,	Carbon Run,	Kendrick & Co.,	95,036	99,390
3	Royal Oak,	Shamokin,	Tillet & Brother,	4,802	3,850

3	Buck Ridge,	Shamokin,	May Audenried & Co.,	30,015	66,555
3	Cameron,	"	Mineral R. R. and Mining Co.,	175,655	164,596
3	Luke Fidler.	"	" "	140,291	124,974
3	Pennsylvania,	Green Ridge,	" "	118,837	125,167
3	Hickory Ridge,	Coal Run,	" "	22,311	23,640
3	Lancaster,	"	Smythe & Keyser,	30,806	22,752
3	Carson,	Shamokin,	M. E. Robinson,	14,416	8,070
3	Greenback,	Greenback,	H. J. Tondy,	30,358	42,515
				1,410,830	1,373,945

12. *Panther Creek District.*

6	Breaker No. 3,	Nesquehoning,	Lehigh Coal & Navigation Co.,	136,150	114,693
6	Breaker No. 4,	Jamestown,	" "	54,324	127,411
6	Breaker No. 5,	Andrewsville,	" "	73,240	71,585
6	Breaker No. 6,	"	" "	91,551	79,867
6	Breaker No. 9,	Coaldale,	" "	59,133	
1	Breaker No. 8,	"	" "	140,365	107,424
1	Breaker No. 10,	Bull Run,	" "	86,463	116,259
1	Breaker No. 11,	"	" "	81,525	76,955
1	Greenwood,	Tamaqua,	Raabe & Fey,	2,776	2,480
1	West Lehigh,	"	Wood & Pearce,	16,500	12,000
				742,027	708,674

13. *East Schuylkill District.*

1	Pinedale,	Middleport,	Louis Lorenz,	6,600	1,828
1	Pine Forest,	St. Clair,	Phila. & Read. Coal & Iron Co.,	41,549	42,486
1	Eagle,	"	George W. Johns & Bro.,	49,361	28,594
1	Beechwood,	Mt. Laffee,	Phila. & Read. Coal & Iron Co.,	39,706	31,920
1	Wadesville,	Wadesville,	" "	110,874	15,233
1	Eagle Hill,	New Philadelphia,	" "	70,084	69,812
1	Pottsville,	Pottsville,	" "	16,478	42,626

13. *East Schuylkill District—Continued.*

No. of Inspector's dis.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
1	Palmer Vein,	New Philadelphia,	Alliance Coal Co.,	28,000	35,596
1	St. Clair,	St. Clair,	Atkinson & Lessig,	3,524	4,858
1	Sharp Mountain,	Pottsville,	Thomas Wren,	2,540	1,266
1	Monitor,	Wadesville,	John H. Denning,	1,854	2,840
1	Peach Orchard,	St. Clair,	"	1,362	261
1	Peach Orchard,	"	Thomas Burke,	235	9
1	Middle Lehigh,	New Boston,	Mill Creek Coal Co.,	153,924	146,432
1	East Lehigh,	Mahanoy City,	Mitchel & Symonds,	10,116	8,461
1	Repplier,	New Castle,	J. F. Quinn,	3,106	4,251
1	Mammoth,	Broad Mountain,	Mahany & Co.,	750	
1	Furnace,	St. Clair,	John Wylam,	129	50
1	Keim & Repp,	Mill Creek,	Samuel B. Myers,	165	151
1	Garfield,		Tim Cockhill,	252	
1	North Dale,	Middleport,	Alliance Coal Co.,		2,968
1	Oak Hill,	Mt. Laffee,	Martin Devlin,		320
1	New Castle,	New Castle,	B. F. Palm & Son,		659
1	Corinda,	Wadesville,	George Morgan,		919
1	Oakwood,	New Castle Station,	John Botham & Co.,		1,000
1	Morning Star,	" "	Whyms & Morgan,		560
1			Theodore Hellman,	637	
				541,246	443,100

14. *West Schuylkill District.*

1	Gate Vein,	Minersville,	George Wilson,		31
1	Mine Hill Gap,	"	Phila. & Read. Coal & Iron Co.,	48,902	51,540

1	Thomaston,	Heckersville,	Phila. & Read. Coal & Iron Co.,	82,975	70,784
1	Richardson,	Glen Carbon,	" "	58,388	66,381
1	Glendower,	"	" "	51,465	1,221
1	Phœnix Park, No. 2,	Phœnix Park,	" "	33,011	32,964
1	Phœnix Park, No. 3,	"	" "	22,163	30,676
1	Black Mine,	Llewellyn,	J. D. Curtz Crook,	16,357	5,620
1	Ellsworth,	New Castle,	John R. Davis,	11,933	15,036
1	Black Valley,	Minersville,	Ed. Hoskins,	1,942	1,667
1	Dundas,	"	Davis & Co.,	5,000	9,982
1	Juguiar,	New Castle,	Jacob S. Hepner,	869	1,050
1	Swatara,	Swatara,	Phila. & Read. Coal & Iron Co.,	53,124	41,725
1	Otto,	Branch Dale,	" "	55,905	11,422
1	Black Heath,	Minersville,	William Harris,	21,132	6,245
1	Chandler,	"	Patrick Keenan,	100	. . . . . .
1	Lewis Tract,	"	George Harris,	207	. . . . .
1	Swatara,	Swatara,	John D. Felty,	1,046	882
1	Chandler Tract,	Minersville,	William Lloyd,	9	. . . . .
1	Wolf Creek Big Diamond,	Wolf Creek,	Jas. F. Donahoe,	8,000	5,860
1	Wolf Creek Diamond,	Minersville,	John A. Lawrence,	5,624	2,205
1	Forestville,	Forestville,	Phila. & Read. Coal & Iron Co ,	7	11,443
1	Middle Creek,	Swatara,	" "	2	4,872
1	Kirk Line,	Thomastown,	P. O'Conner,	. . . .	219
1	Crystal,	New Castle,	Joseph Brady,	. . . .	5,150
1	Jonestown,	Primrose,	T. F. Gwinn,	. . . .	350
1	Black Heath,	Wolf Creek,	George Kantner,	. . . . .	729
				478,161	378,054

15. Lorberry District.

1	Colket,	Donaldson,	Phila. & Read. Coal & Iron Co.,	43,221	31,484
1	East Franklin,	Upper Rausch Creek,	" "	19,179	25,052
1	Lower Rausch Creek,	Tremont township,	Miller, Graeff & Co.,	85,382	62,683
1	Tremont Lands,	Tremont,	Peter Laux,	131	Abandoned.
1	Woods,	"	Geo. S. Woods,	1,054	887
				148,967	120,106

16. *Lykens Valley District.*

No. of Inspect'rs. dist.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
1	Lincoln,	Tremont township,	Levi Miller & Co.,	146,899	165,679
1	Kalmia,	Orwin,	Phillips & Sheafer,	83,167	201,100
3	West Brookside,	Porter township,	Phila. & Read. Coal & Iron Co.,	374,533	289,892
3	Williamstown,	Williamstown,	Summit Branch R. R. Co.,	279,790	342,218
3	Short Mountain,	Lykenstown,	Short Mtn. & Lykens Val. C. Co.,	198,188	195,096
3	Big Run Gap,	Williams Valley,	James Fennel,	2,628	2,498
				1,085,205	1,196,483
	Total reported as shipped from collieries,			28,776,980	29,439,947
	" " as consumed at and about collieries,			1,760,601	1,841,119
	Total Production Hard Anthracite,			30,537,581	31,281,066

17. *Loyalsock Basin.*

No. of Inspect'rs. dist.	Name of Colliery, 1882.	Location.	Operator, 1882.	Tons. 1881.	Tons. 1882.
	Bernice,	Bernice, Sullivan county,	State Line & Sullivan R. R. Co.,	*64,325	77,198
	Total Production Anthracite Coal Fields,			30,601,906	31,358,264

*The Bureau of Industrial Statistics (Harrisburg) reports the production of this field for 1881 as 14,000 tons. After this tonnage had been printed on Miscellaneous sheet No. II, and when it was too late for correction, it was ascertained that the report published by the Bureau was obtained from one of the subordinate employés of the company and was 50,000 tons less than the amount of coal actually produced.

3. TABLE NO. II.—*Total Production and Shipment from the Mine Inspectors districts for the years 1881 and 1882, with the Colliery and local consumption.*

DISTRICT.	No.	Inspector.	Shipment.	Colliery and local consumption, 1881.	Total production.	Shipment.	Colliery and local consumption, 1882.	Total production.
First Schuylkill,	1	Samuel Gay,	1,726,069	103,566	1,829,635	1,623,157	97,389	1,720.546
Second Schuylkill,	2	Robert Mauchline,	4,248,666	254,980	4,503,646	4,403,892	264,234	4,668,126
Third Schuylkill,	3	James Ryan,	4,181,679	250,904	4,432,583	4,323,051	259,383	4,582,434
Middle Carbon & Luzerne,	4	G: M. Williams,	6,624,061	397,444	7,021,505	6,659,762	399,586	7,059,348
Eastern Carbon & Luzerne,	5	Patrick Blewitt,	7,310,042	402,222	7,712,264	7,439,385	446,363	7,885,748
Southern Carbon & Luzerne	6	Jas. E. Roderick,	4,686,463	351,485	5,037,948	4,990,700	374,164	5,364,864
Total production Hard Anthracite,			28,776,980	1,760,601	30,537,581	29,439,947	1,841,119	31,281,066
Loyalsock Field Sullivan County (soft Anthracite,)					64,325	. . . .	. . . .	77,198
Total Production all anthracites,					30,601,906	. . . .	. . . .	31,358,264

Some of the mine inspectors report the annual shipment of coal from each colliery and add a fixed percentage for local sales and colliery consumption to the total shipments, in order to obtain the total production;* others report the total production of each colliery; while in still other cases both the shipment and production of each colliery is given.

By reference to the following table the reader may ascertain whether the shipment or production has been reported for the different districts in this report, and the way in which Table II has been compiled:

Report for 1881.

No. of District.	Shipment.	Production.
1	Reported for each colliery.	Total obtained by adding total colliery consumption reported to total shipment.
2	Reported for each colliery.	Total obtained by adding total colliery consumption reported to total shipment.
3	Reported for each colliery.	Total obtained by adding total colliery consumption reported to total shipment.
4	Total obtained by assuming total colliery consumption to have been 6% of total shipment.	Reported for each colliery.
5	Reported for each colliery.	Total obtained by adding the total colliery consumption reported, and 35,000 tons for local sales, to the total shipment.
6	Total obtained by assuming total colliery consumption to have been 7.5% of total shipment, same as reported for 1882.	Reported for each colliery.

*In several of the reports what is evidently the colliery shipment is given in a column headed "Number of tons of coal mined." I infer this from the fact, that, to the totals of these columns, a number of tons are added for *colliery consumption.* The confusion which now exists in these reports could be readily obviated by all the mine inspectors adopting a uniform plan of tabulating the colliery shipment and production returns.

Report for 1882.

No. of District.	Shipment.	Production.
1	Reported for each colliery.	Total obtained by adding 6% to total shipment.
2	Total obtained by assuming total colliery consumption to have been 6% of total shipment.	Reported for each colliery.
3	Reported for each colliery.	Total obtained by adding 6% to total shipment.
4	Total obtained by assuming total colliery consumption to have been 6% of total shipment.	Reported for each colliery.
5	Reported for each colliery.	Total obtained by adding 6% to total shipment.
6	Reported to Survey for each colliery, but not given in inspector's report.	Reported for each colliery, as given in table in this report.

In published references, made to the anthracite region, Mr. Jones' report of the total annual shipment is generally spoken of as the total production. If the Mine Inspectors' reports be accepted, for the production, and Mr. Jones' report for the shipment, it will be noted that the total annual production for 1881* (30,537,581 tons) was 2,037,564 tons in excess of the total annual shipment (28,500,017 tons) carried by ten different transporting companies ; in 1882 the total production (31,281,066 tons) was 2,160,970 tons in excess of the total shipment, (29,120,096 tons.)

Various reports are made of the production and shipment of coal from the Anthracite Fields as shown by the following figures for 1881. Much confusion has resulted from these conflicting reports.

	Tons.
Total production, Bureau of Statistics, . . .	27,929,128.18
Total shipment, mine inspectors, ...	28,776,980
Total production, mine inspectors, ...	30,537,581
Total shipment, John H. Jones, ...	28,500,017

*The Loyalsock field has not been included in these estimates.

Total shipment, R. P. Rothwell, editor *Engineering and Mining Journal*, ...	27,208,524
Total production, R. P. Rothwell, editor *Engineering and Mining Journal*, ...	30,261,940

The shipment reported by the mine inspectors is necessarily in excess of the shipment reported by Mr. Jones, as it evidently contains local shipments which have not been made by the transportation companies included in Mr. Jones' list.

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4. TABLE NO. III.—*Total Production of the Anthracite Fields for 1882, by Counties.*

Name of County.	*Tons.*
Susquehanna,	15,333
Lackawanna,	6,071,716
Luzerne,	13,355,316
Carbon,	867,595
Schuylkill,	7,176,489
Columbia,	669,870
Northumberland,	2,552,547
Dauphin,	572,200
Total hard anthracite,	31,281,066
Sullivan, (soft anthracite,)	77,198
Total all anthracites,	31,358,264

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5. *Columnar Sections showing the average thickness of the Coal Measures in the different Anthracite Fields.*

It is impossible for the Survey, at this early stage of the work, to systematize the various columnar sections which have been constructed in the different parts of the region to show the number, thickness, and identity of the coal beds; certains sections, of those which have been reported to the Survey, have, however, been selected, in order to exhibit in a general way, the local names, the thickness, and the relation of the coal beds; and the thickness of the Carboniferous formation which is known at present to contain workable coals.

An important question, to be examined and reported on by the Survey, is the identification of the coal beds which are being worked in the mines of the same, or of different basins. The difficulties in the way of a solution of this problem are very great, and in special localities are appreciated by those practically interested. The information which is in the possession of any one engineer in the region, however extensive his connections, is seldom such as to enable him to identify the beds over any very considerable area; certainly not for the entire coal field.

The idea is prevalent, that the identity and relation of the coal-beds have been established beyond doubt, and that certain of the anthracite beds have been identified as the representatives of the bituminous beds in the western part of the State. To what extent this has been accomplished, as far as the anthracite beds are concerned, the facts presented here will show.*

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* Prof. Rogers in his final report of the First Geological Survey, published in 1858, attempted to systematize the conflicting names assigned to the coal-beds. The information which the assistant geologists were able to obtain at that time was too meagre to permit of a rectification of all of the inconsistencies. In some localities, where it was believed that the same bed had been given different names, too little was certainly known of the structure to permit of a final solution. In introducing this subject Prof. Rogers says: "Much pains have been devoted, in the progress of the Geological Survey of the Anthracite region, to noting and recording the characteristic features of the individual coal-seams, to tracing the variations of type which they undergo, to ascertaining their identity from section to section, and the double names which many of them possess. From the circumstances that, from the commencement of mining operations, in the southern basin especially, down to the present day, the chief collieries and explorations for coal have started in the valleys which intersect the basins, the identity of the beds, from valley to valley, remains even yet imperfectly known. In the absence of such knowledge of the equivalencies of the locally opened beds, it was natural, indeed inevitable, that the miners should assign either local names, or apply the known names of distant coals erroneously to their own favorite seams. A desire to apply to a newly-found coal, or a newly-organized mine, the name of some bed of established repute nearly in the same range with it, where a scrupulous tracing of their outcrops might have proved them dissimilar, has added not a little to the excessive confusion of nomenclature which now exists, to the serious detriment of the mining interests of the region."

"Not a few of the disastrous disappointments which attend mining enterprise in the Pottsville basin, may be attributed to the prevailing ignorance of the true range and identity of its coal-beds; one main source of which, next to a want of clear tracing of the anticlinal and synclinal flexures, is the confusion in the namingof the coal-beds."

Since the Second Geological Survey has been in progress, numerous demands have been made for columnar sections of the coal measures, in special localities, in order to determine the identity and relation of particular coal-beds. As the detailed information in the possession of the Survey will not be available to the public, until it is systematized and results deduced and placed in form to be published, it has not yet been possible to meet these requests. The importance of this question to the property owner and miner will be appreciated, when it is considered that, if it is not certainly known what coal-bed is being mined, the number or character of the coal-beds above or below it can only be a matter of conjecture. The anthracite coal-beds have all, long since, been named; and in many instances the same names have been indelibly affixed to beds of well-recognized characteristics over the entire region from Scranton to Tremont. The natural inference has been that any one of these well-known names designates always the same bed, wherever it may be used. In many cases this is a fact; in many others the supposed identification of the beds has been established upon insufficient grounds and a similarity of name does not necessarily indicate an identity of beds.*

In the case of some of the large mining companies, whose operations are spread over a vast territory, this subject has received a careful study from their engineers and colliery superintendents, and the relationship of the beds has been established. Notable instances could be named, however, where a mistaken identity of the beds, on properties immediately adjoining those of the larger companies, has not only produced complications in mining, but has increased or depreciated property values. In general, these errors have come from a supposed parallelism of the coal-beds, or from placing too much importance upon a similarity of coal as indicative of an identity of bed. The non-parallelism of the anthracite beds in many localities is now proved beyond a question; in fact, it is doubted whether the certain identification of any of the Carboniferous strata, over the entire

* A short time ago I was informed, on good authority, that a bed being worked in a certain mine had been named after another bed mined elsewhere, because the latter produced a grade of coal which stood high in the market.

coal-field can be accepted, other than the Mammoth bed and the base of the Pottsville Conglomerate, No. XII (Carboniferous Conglomerate, Millstone Grit, or Seral of Rogers). Even in these two cases instances could be cited which have recently caused the assistants of the Survey much perplexity. These difficulties have arisen in parts of the coal basins which have been most thoroughly and longest worked.

The following sections, which have been measured by different engineers in prominent localities throughout the region, show the best known local names, and the relation of the coal-beds, together with their average thickness, and the thickness of the Carboniferous formation* in the several basins which is known at present to contain workable beds. A typical section in each basin has been selected and placed on Miscellaneous sheet No. II, so that the bottom of the Mammoth bed, so called, in each case is on a horizontal line across the sheet. In most cases it is quite impossible at present to identify the individual beds from section to section.

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* It is difficult, without a very careful survey, to state any thickness for a coal-bed, or for the rock intervals between the beds, which shall be an average for any area, as both are known to change within very short distances. A notable instance, as regards the coal, is found in the No. 9 Colliery of the Lehigh Coal and Navigation Company, as is shown in the following table, (vid. Columnar section No. 20, sheet No. III:)

Distance from Tunnel No. 9.	*Thickness of Mammoth Coal-Bed.*	*Thickness of coal.*
4129 feet east,	49	42.5
3926 " west,	73	66
4017 " "	114	106

In the latter locality it was difficult to determine the average dip of the coal-bed, and the thickness which has been assigned to it is, without doubt, an abnormal one. The locality where the section was measured, as reported by Mr. Rutter, is now (1883) under water, and I was unable to visit it.

On the property of the same company, the interval between the top of the Mammoth bed and the bottom of the Red Ash, F, or Primrose bed, varies from 164 feet at Tunnel No. 1, to 287 feet at Tunnel No. 9, which is six miles west of Tunnel No. 1.

6. Northern Coal Field.

Section No. 1.—Carbondale Basin, Forest City Colliery—Authority: Hillside Coal and Iron Company.

	Rock.		Coal beds.*		Total.	
1. Surface,	22′				to 22′	
2. Sandstone,	26′				to 48′	
3. Coal bed,			2′		to 50′	
4. Slate,	12′				to 62′	
5. Coal bed,			6′		to 68′	
6. Slate,	6′				to 74′	
7. Sandstone,	27′				to 101′	
8. Coal bed,				6″	to 101′	6″
9. Sandstone,	32′	8″			to 134′	2″
10. Slate,	2′	6″			to 136′	8″
11. Coal bed,				2″	to 136′	10″
12. Slate,	22′	6″			to 159′	4″
13. Coal bed,			1′	6″	to 160′	10″
14. Dirt,		6″			to 161′	4″
15. Coal bed,			2′	2″	to 163′	6″
16. Slate,	13′	6″			to 177′	
17. Sandstone,	14′				to 191′	
18. Slate,	5′				to 196′	
19. Coal bed,				6″	to 196′	6″
20. Slate,		5″			to 196′	11″
21. Coal bed,				6″	to 197′	5″
22. Slate and coal mixed,	1′	7″			to 199′	
23. Sandstone,	11′	5″			to 210′	5″
24. Pea conglomerate,	1′				to 211′	5″
25. Sandstone,	42′	10″			to 254′	3″
26. Slate,	12′				to 266′	3″
27. Sandstone,	12′				to 278′	3″
28. Coal bed,			1′	8″	to 279′	11″
29. Slate,	2′	2″			to 282′	1″
30. Coal bed,			4′	6″	to 286′	7″
31. Slate,	2′				to 288′	7″
32. Sandstone,	4′				to 292′	7″
33. Conglomerate,	4′				to 296′	7″
34. Sandstone,	16′				to 312′	7″
35. Conglomerate,	4′				to 316′	7″
36. Sandstone,	6′	6″			to 323′	1″
37. Slate,	2′	4″			to 325′	5″
38. Pea conglomerate,	1′	8″			to 327′	1″
Total thickness of rock,	307′	7″				
" " coal beds,			19′	6″		

*The measurements, given under "Coal-beds" in each section, are necessarily very much in excess of the thickness of coal contained in the beds, as they include the several coal benches with the separating material.

Section No. 2.—Carbondale Basin, Vicinity of Carbondale.—Authority: Hillside Coal and Iron Company.

	Rock.		Coal beds.		Total.	
1. Surface,	12′				to 12′	
2. Sandstone,	8′	6″			to 20′	6″
3. COAL BED,			2′	3″	to 22′	9″
4. Sandstone,	25′	4″			to 48′	1″
5. COAL BED,			1′	8″	to 49′	9″
6. Sandstone,	8′	3″			to 58′	
7. Slate,	6′				to 64′	
8. COAL BED,				4″	to 64′	4″
9. Slate,	9′				to 73′	4″
10. ARCHBALD OR CARBONDALE COAL BED,			7′		to 80′	4″
11. Slate,	4′	6″			to 84′	10″
12. Sandstone,	32′				to 116′	10″
13. Slate,	5′				to 121′	10″
14. COAL BED,				10″	to 122′	8″
15. Slate,	3′	5″			to 126′	1″
16. Sandstone,	39′	6″			to 165′	7″
17. Slate,		3″			to 165′	10″
18. COAL BED,				7″	to 166′	5″
19. Slate,	13′				to 179′	5″
20. COAL BED,				2″	to 179′	7″
21. Slate,	4′	10″			to 184′	5″
22. Sandstone,	22′				to 206′	5″
23. Slate,	7′				to 213′	5″
24. Sandstone,	37′				to 250′	5″
25. COAL BED,				2″	to 250′	7″
26. Pea conglomerate,	12′				to 262′	7″
27. Conglomerate,	4′				to 266′	7″
28. Pea conglomerate,	10′				to 276′	7″
29. Conglomerate,	9′	5″			to 286′	
30. Slate,	1′				to 287′	
31. Coarse conglomerate,	8′	2″			to 295′	2″
Total thickness of rock,	282′	2″				
" " coal beds,			13′			

Section No. 3.—Lackawanna Basin, Vicinity of Scranton.—Authority: Delaware, Lackawanna and Western R. R. Co.

	Rock.	Coal Beds.	Total.
1. Surface,	35′		to 35′
2. A COAL BED[1],		10′	to 45′
3. Rock,	89′		to 134′
4. B COAL BED[2],		2′	to 136′
5. Rock,	45′		to 181′
6. C COAL BED[3],		6′	to 187′

	Rock.	Coal Beds.	Total.
7. Rock	32′		to 219′
8. D COAL BED[4], ...		7′	to 226′
9. Rock, ...	90′		to 316′
10. E, OR DIAMOND COAL BED,		6′	to 322′
11. Rock, ...	39′		to 361′
12. F, OR ROCK COAL BED, . . .		6′	to 367′
13. Rock, . .	117′		to 484′
14. G, OR BIG (BALTIMORE?) COAL BED, ...		10′	to 494′
15. Rock, . . .	53′		to 547′
16. H, OR NEW COUNTY COAL BED, ...		5′	to 552′
17. Rock, ...	40′		to 592′
18. J, OR CLARK COAL BED, .		6′	to 598′
19. Rock, ...	52′		to 650′
20. K COAL BED, ...		4′	to 654′
21. Rock, ...	41′		to 695′
22. L COAL BED, ...		5′	to 700′
Total thickness of rock, . .	633′		
" " coal beds,		67′	

NOTES 1. Only found to outcrop at two points in the valley.

2. Not workable anywhere.

3. Very rough bony coal not mined by D., L. & W. R. R. Co. anywhere.

4. Rough coal 2′ of slate in center of bed not mined by the company anywhere.

Section No. 4.—Wilkes Barre Basin, Conyngham Shaft and Baltimore Bore-hole.—Authority: Lehigh and Wilkes Barre Coal Company, and Delaware and Hudson Canal Company.

Conyngham Shaft.		*Rock.*		*Coal Beds.*			*Total.*	
1. Masonry, ...		19′	9″			to	19′	9″
2. Fine sandstone, ...		22′	2″			to	41′	11″
3. Fine slate, ...		11′	3″			to	53′	2″
4. Sandstone, ...		6′	11″			to	60′	1″
5. COAL,	K COAL BED			3′	7″	to	63′	8″
6. Slate,	K COAL BED	3′	6″			to	67′	2″
7. COAL and slate	K COAL BED			4′	1″	to	71′	3″
8. Slate and rock, ...		14′	3″			to	85′	6″
9. Sandstone, ...		19′	8″			to	105′	2″
10. Pebble rock, ...		10′	10″			to	116′	
11. Black sandstone, ...		12′	9″			to	128′	9″
12. Slate, ...		3′	1″			to	131′	10″
13. J, SEVEN FOOT, or ABBOTT COAL BED, ...				4	6″	to	136′	4″
14. Slaty sandstone, ...		51′	3″			to	187′	7″
15. Pebble rock, ...		10′	3″			to	197′	10″
16. Gray sandstone, ...		15′	2″			to	213′	

17. I, Kidney, or Bowkley coal bed, ...			4′	7″	to 217′ 7″
18. Slate, ...	16′	7″			to 234′ 2″
19. Pebble rock, ...	28′	6″			to 262′ 8″
20. Black slate, ...	6′	7″			to 269′ 3″
21. Coal, } H, or Hillman coal bed, . .			4′		to 273′ 3″
22. Coal, } H, or Hillman coal bed, . .			11′	11″	to 285′ 2″
23. Slate, ...	7′	5″			to 292′ 7″
24. Pebble rock, ...	50′	6″			to 343′ 1″
25. Black slate, ...		9″			to 343′ 10″
26. Pebble rock, ...	80′	7″			to 424′ 5″
27. Slate, ...	10′	3″			to 434′ 8″
28. G coal bed, ...			2′	8″	to 437′ 4″
29. Black slate, sand, and coal, .	1′	9″			to 439′ 1″
30. Fine dark sandstone, ...	30′	4″			to 469′ 5″
31. Micaceous fine sandstone, . .	15′	10″			to 485′ 3″
32. Fine dark sandstone, ...	8′	3″			to 493′ 6″
33. Dark sandstone, ...		11″			to 494′ 5″
34. Coal and slate, F (Five-foot ?) coal bed, . . .			2′	8″	to 497′ 1″
35. Fine dark sandstone and fire-clay, ...	12′	4″			to 509′ 5″
36. Fine dark sandstone and fire-clay, ...	18′	4″			to 527′ 9″
37. Fine and hard mica iron-stone,	36′	10″			to 564′ 7″
38. Fire-clay and iron-stone, . .	6′	3″			to 570′ 10″
39. Fine micaceous iron-stone, .	53′	10″			to 624′ 8″
40.–49. } E, or Baltimore coal bed.					
40. Bone, .		5″			to 625′ 1″
41. Coal, .				7″	to 625′ 8″
42. Slate and bone,		9″			to 626′ 5″
43. Coal, .				11″	to 627′ 4″
44. Bone, .		2″			to 627′ 6″
45. Coal, .			5′	10″	to 633′ 4″
46. Slate, . .		2″			to 633′ 6″
47. Coal, .			2′	6″	to 636′
48. Dirt, .		7″			to 636′ 7″
49. Coal, .			4′		to 640′ 7″
Baltimore Bore Hole.					
50. Rock, ...	98′				to 738′ 7″
51. Slate, ...	7′	11″			to 746′ 6″
52. Coal bed, ...			2′		to 748′ 6″
53. Slate, ...	1′	10″			to 750′ 4″
54. Rock, ...	23′	5″			to 773′ 9″
55. Slate, ...		5″			to 774′ 2″
56. Coal bed, ...				8″	to 774′ 10″
57. Slate, ...	2′	3″			to 777′ 1″
58. Rock, ...	85′				to 862′ 1″
59. Slate, ...		6″			to 862′ 7″
60. D (?) coal bed, ...			3′	8″	to 866′ 3″
61. Slate, ...	6′	6″			to 872′ 9″

	Rock.	Coal Beds.	Total.
62. COAL BED, ...		10″	to 873′ 7″
63. Slate, ...	21′ 4″		to 894′ 11″
64. COAL, } C, OR ROSS COAL BED.		4′ 8″	to 899′ 7″
65. Slate, } C, OR ROSS COAL BED.	6″		to 900′ 1′
66. COAL, } C, OR ROSS COAL BED.		1′ 6″	to 901′ 7″
67. Rock, ...	28′		to 929′ 7″
68. COAL, 69. Slate, 70. Bone, } B, OR RED ASH COAL BED.		17′ 3″	to 946′ 10″
Red Ash Colliery Bore Hole.			
71. Slate, ...	2′ 10″		to 949′ 8″
72. A COAL BED, ...		2′ 10″	to 952′ 6″
Total thickness of rock,	867′ 3″		
" " coal beds,		85′ 3″	

Section No. 5.—Nanticoke Basin, Susquehanna Shafts Nos. 1 and 2.—Authority: Susquehanna Coal Company.

Shaft No. 1.	*Rock.*	*Coal Beds.*	*Total.*
1. Surface, ...	16′ 10″		to 16′ 10″
2. Shelly sandstone, ...	3′ 6″		to 20′ 4″
3. Shelly sandstone, ...	23′ 4″		to 43′ 8″
4. Soft sandstone, ...	35′ 10″		to 79′ 6″
5. Fire-clay, ...	3′ 6″		to 83′
6. COAL BED, ...		2′ 6″	to 85′ 6″
7. Black slate, ...	13′ 3″		to 98′ 9″
8. Hard sandstone, ...	4′		to 102′ 9″
9. Slate, ...	5′ 11″		to 108′ 8″
10. DIAMOND, GEORGE, OR I COAL BED, ...		4′ 6″	to 113′ 2″
11. Slaty sandstone and iron balls	45′ 2″		to 158′ 4″
12. Hard sandstone, ...	24′ 10″		to 183′ 2″
13. Micaceous sandstone, . . .	10′ 11″		to 194′ 1″
14. Slate, ...	8′ 11″		to 203′
15. COAL BED, ...		1′ 6″	to 204′ 6″
16. Slate and slaty sandstone, .	20′ 1′		to 224′ 7″
17. COAL and gas, ...		3″	to 224′ 10″
18. Slaty sandstone, ...	24′ 10″		to 249′ 8″
19. Hard sandstone, ...	19′ 6″		to 269′ 2″
20. Slaty sandstone and slate, .	16′ 11″		to 286′ 1″
21. ORCHARD, TUNNEL, OR H COAL BED, ...		10′ 1″	to 296′ 2″
22. Slate and slaty sandstone, .	23′ 10″		to 320′
23. COAL BED, ...		2″	to 320 2″
24. Soft slaty sandstone, ...	9′ 11″		to 330′ 1″
25. Firm sandstone, ...	11′ 11″		to 342′
26. Slate and sandstone, ...	22′		to 364′
27. Fire-clay, ...	4′ 6″		to 368′ 6″
28. HILLMAN, SLOPE, OR G COAL BED, ...		7′ 11″	to 376′ 5″
29. Fire-clay and slate, ...	2′		to 378′ 5″

30. Firm micaceous sandstone, .	29′ 10″		to 408′ 3″
31. Firm slate, ...	14′ 11″		to 423′ 2″
32. COAL BED (COAL and bone,)		2′ 6″	to 425′ 8″
33. Slate, ...	3′ 6″		to 429′ 2″
34 Sandstone, ...	9′ 11″		to 439′ 1′
35. LANCE OR FOUR FOOT COAL BED, ...		5′	to 444′ 1″
36. Slate and sandstone, ...	34′ 10″		to 478′ 11″
37. COOPER COAL BED, ...		9′ 11″	to 488′ 10″
38. Curly slate and COAL, . . .	7′ 11″		to 496′ 9″
39. Sandy slate, ...	11′ 11″		to 508′ 8″
40. Dark sandstone, ...	17′ 2″		to 525′ 10″
41. BENNETT, FORGE, or E COAL BED, ...		6′ 9″	to 532′ 7″
42. Slate, ...	3′		to 535′ 7″
43. Short fracture sandstone, . . *Shaft No. 2.*	30′ 4″		to 565′ 11″
44. Carbonaceous mixture, COAL, &c., ...		6″	to 566′ 5″
45. Hard sandstone, ...	12′		to 578′ 5″
46. Fine conglomerate and sandstone, ...	42′ 1″		to 620′ 6″
47. Hard black sandstone, . .	32′ 6″		to 653′
48. TWIN COAL BED, TOP BENCH		6′ 3″	to 659′ 3″
49. Slate, ...	6′ 5″		to 665′ 8″
50. COAL BED, ...		1′ 3″	to 666′ 11″
51. Slate and fire-clay, ...	1′ 5″		to 668′ 4″
52. TWIN COAL BED, BOTTOM BENCH, ...		4′ 5″	to 672′ 9″
53. Slate, ...	18′ 10″		to 691′ 7″
54. COAL BED, ...		2′ 4″	to 693′ 11″
55. Slate and sandstone, ...	30′ 4″		to 724′ 3″
56. Hard quartz, (wedge,) . . .	21′ 9″		to 746′
57. Slate and sandstone, ...	26′ 1″		to 772′ 1″
58. Firm sandstone, ...	11′ 11″		to 784′
59. COAL BED, ...		2″	to 784′ 2″
60. Sandy slate and hard sandstone, ...	13′ 8″		to 797′ 10″
61. Close hard sandstone, ...	14′ 10″		to 812′ 8″
62. Slate, ...	3′ 11″		to 816′ 7″
63. ROSS OR C COAL BED, ...		5′ 6″	to 822′ 1″
64. Hard sandstone, ...	11′ 11″		to 834′
65. Firm slaty sandstone, . . .	16′ 5″		to 850′ 5″
66. THREE-FOOT COAL BED, . .		2′ 11″	to 853′ 4″
67. Slate and hard bastard conglomerate, ...	51′ 10″		to 905′ 2″
68. COAL BED, ...		3′ 1″	to 908′ 3″
69. Slate, sandstone, and bastard conglomerate, ...	37′ 2″		to 945′ 5″
70. COAL BED, ...		2′	to 947′ 5″
71. Slate, ...	5″		to 947′ 10″
72. Bastard conglomerate, . . .	36′ 9″		to 984′ 7″

73. BUCK MOUNTAIN OR B COAL BED, ...		10′	to 994′	7″
74. Slate, ...	12′ 11″		to 1007′	6″
75. RED ASH COAL BED, ...		6′	to 1013′	6″
Total thickness of rock, . . .	918′			
" " coal beds,		95′ 6″		

These sections are of great local interest and value, and show the exact stratification of the coal measures at Nanticoke, Wilkes Barre, Scranton, Carbondale, and in the vicinity of Forest City colliery in the Northern (Wyoming and Lackawanna) coal field. The difficulty of selecting a section in this field, typical of any considerable area, has been greater than in the more southern fields. The development and mining of coal in the Northern Field has been more independently conducted, and there has been less interchange of information between the mining engineers and operators than elsewhere. In addition to this, the mines are more scattered and, in the main, the basins are shallower than in the Schuylkill regions. As a result, there are not as many different beds being mined in special areas. These facts have rendered it very difficult for the beds to be properly identified, and the work which is left here for the Geological Survey, is probably greater and beset with more embarrassments than anywhere else; although in no region is this kind of information more desired or more necessary to the property owners. A great many records of shafts and diamond-drill holes have been obtained by Mr. Frank A. Hill and his assistants in the Wilkes Barre office. Many of these are held confidentially, until they shall be finally systematized and arranged for general publication; so that it is impossible, at present, to even suggest a final comparison of the beds given in the Northern Coal Field sections. On Miscellaneous sheet No. II the sections have been placed so that, what is generally considered to be the representative of the Mammoth bed is placed horizontally opposite the Mammoth bed in the Lehigh and Schuylkill sections. The confusion of names is very great in this field; for instance, the Hillman bed is known also as the Slope, G or H bed. The next bed above this one is known locally as the Lance, Kidney, Bowkley, Mills, Orchard, or Tunnel bed.

The bed above this one is locally known by the following names, Hutchinson, Seven-Foot, Diamond, George. A study and comparison of these sections cannot fail to convince the most indifferent, of the necessity of a thorough and exhaustive examination of this and of the other anthracite coal basins.

The thicknesses of the beds are subject to many local changes, and in special localities may be more or less than given here.

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7. *Eastern Middle Field.*

Section No. 6.—Black Creek Basin, Gowen Bore Hole No. 1.—Authority: Coxe Brothers & Co.

		Rock.	*Coal Beds.*	*Coal.*
1. Surface,		3′		to 3′
2. Gray rock,		9′ 6″		to 12′ 6″
3. Dark sand-slate,		1′ 7″		to 14′ 1″
4. Fine sand-rock,		8′ 10″		to 22′ 11″
5. Gray rock,		13′ 7″		to 36′ 6″
6. Black slate,		2′ 2″		to 38′ 8″
7. COAL BED,	First coal bed below Mammoth bed.		2″	to 38′ 10″
8. Slate,		4″		to 39′ 2″
9. COAL BED,			2′ 3″	to 41′ 5″
10. Black slate,		1′ 8″		to 43′ 1″
11. COAL BED,			2′ 5″	to 45′ 6″
12. Black slate,		10′ 3″		to 55′ 9″
13. Sand-rock,		13′ 7″		to 69′ 4″
14. Fine pebble rock,		12′ 6″		to 81′ 10″
15. Black slate,		5′		to 86′ 10″
16. Sand-rock and black slate,		1′ 9″		to 88′ 7″
17. Sand-rock,		3′ 5″		to 92′
18. Soft black slate,		8″		to 92′ 8″
19. COAL,	WHARTON COAL BED.		1″	to 92′ 9″
20. Soft black slate,		9″		to 93′ 6″
21. COAL,			6′ 4″	to 99′ 10″
22. Slate,		11′ 8″		to 111′ 6″
23. Bony slate,		7″		to 112′ 1″
24. COAL,			4′ 1″	to 116′ 2″
25. Slate,		5″		to 116′ 7″
26. COAL, bony,			1″	to 116′ 8″
27. Fire-clay,		8′ 11″		to 125′ 7″
28. Slate,		3′ 3″		to 128′ 10″
29. Sandy slate,		5′ 6″		to 134′ 4″
30. Blue rock,		11′ 7″		to 145′ 11″

31. Pebble rock,	37'	5"			to 183' 4"
32. Slate,	5'	11"			to 189' 3"
33. Sand-rock,	4'				to 193' 3"
34. Pebble rock,	9'	7"			to 202' 10"
35. Black slate,		7"			to 203' 5"
36. GAMMA COAL BED. TOP MEMBER. (Shelly and slaty,)			2'	4"	to 205' 9"
37. Slate,	40'	8"			to 246' 5"
38. GAMMA COAL BED. BOTTOM MEMBER. (Slaty,)			3'	7"	to 250'
39. Dark sand-rock,	23'	7"			to 273' 7"
40. Slate,	8'	2"			to 281' 9"
41. COAL, } BUCK MOUNTAIN COAL BED,			5'	4"	to 287' 1"
42. Slate, } BUCK MOUNTAIN COAL BED,		6"			to 287' 7"
43. COAL, } BUCK MOUNTAIN COAL BED,			7'		to 294' 7"
44. Soft shelly slate,		3"			to 294' 10"
45. Slate,	12'				to 306' 10"
46. Dark sand-rock,	26'	2"			to 333'
47. Pebble rock,	14'	4"			to 347' 4"
48. Black slate,		10"			to 348' 2"
49. COAL, } ALPHA COAL BED.			(½")	1"	to 348' 3"
50. COAL and slate, } ALPHA COAL BED.			3'	8"	to 351' 11"
51. COAL, } ALPHA COAL BED.				3"	to 352' 2"
52. Sand-rock,	3'	8"			to 355' 10"
53. Gray rock,	25'	9"			to 381' 7"
54. Pebble rock,	2'	10"			to 384' 5"
55. Dark sand-rock,	1'				to 385' 5"
56. Black slate,		8"			to 386' 1"
57. Gray rock,	9'	10"			to 395' 11"
58. Conglomerate,	4'	6"			to 400' 5"
59. Gray sandstone,	4'	8'			to 405' 1"
60. COAL BED,				5"	to 405' 6"
61. Dark sand-rock with pebbles,	9'	5"			to 414' 11"
62. Conglomerate,	2'	10"			to 417' 9"
63. Gray rock,	5'	11"			to 423' 8"
64. Dark sand-rock,	1'	3"			to 424' 11"
65. Conglomerate,	39'	8"			to 464' 7"
66. Dark sand-rock,	2'	5"			to 467'
67. Conglomerate,	30'	1"			to 497' 1"
68. Dark sand-rock,	1'	6"			to 498' 7"
69. Conglomerate,	6'				to 504' 7"
70. Slate,	5'	7"			to 510' 2"
71. Green sandstone,	86'				to 596' 2"
Total thickness of rock,	558'	1"			
" " coal beds,			38'	1"	

This section was constructed from the record of a bore-hole drilled by Coxe Brothers and Co. at Gowen, in the West

Cross Creek basin, which is one of the Black Creek basins.* The geology is very much confused at this point, so that the names given to the beds in the section, which were assigned to them at the time the hole was drilled, may not be correct. The hole was bored in 1876; but the engineers of the company consider that they know less about the structure of this basin, and the identity of the beds, than when the diamond-drill core was first studied in 1876, and names given to the different beds. This conclusion, arrived at, after a close and careful study of the facts which have been developed in this basin during six years, is not an exceptional one. Although it is the popular opinion that the geology of the anthracite coal fields has long since been settled, I know of no fresher field for the mining geologist to work in than this, and none where his work, if carefully and intelligently done, would be of more practical and economical value.

The following section represents the strata in the Black Creek basin, midway between Ebervale and Jeddo, on what is known as the Jeddo property, 800 feet east of the Ebervale property.†

	Rock.	*Coal beds.*	*Total.*
1. Interval,	198′		to 198′
2. MAMMOTH COAL BED,		27′	to 225′
3. Interval,	21′		to 246′
4. PARLOR COAL BED,		5′	to 251′
5. Interval,	45′		to 296′
6. WHARTON COAL BED,		2′	to 298′
7. Interval,	46′		to 344′
8. BUCK MOUNTAIN COAL BED,		1′	to 345′
9. Interval,	39′		to 384′
10. A COAL BED,		1′	to 385′
11. Interval,	20′		to 405′
Total thickness of rock,	369′		
" " coal beds,		36′	

*The hole was not drilled perpendicular to the dip of the strata; the record has, however, been reduced, and reported by Mr. Berlin, to show the thickness of each stratum perpendicular to its bedding.

†These two properties are both owned by the Union Improvement Company; that portion known as the Ebervale property is leased and operated by the Ebervale Coal Company; the eastern part of the property, which is generally known by the name of Jeddo, is leased and operated by G. B. Markle & Co.

The Mammoth bed in this section is given as 27 feet thick; this is probably an average, although it is as difficult to assign an average thickness to this bed in the Black Creek basin as anywhere in the region. Calvin Pardee & Co., near Hollywood and Milnesville, are at present stripping this bed in places where it has a thickness between 60 and 90 feet over a large area. In one place, directly in the center of the basin, it measures as much as 102 feet thick. Next to the bed in Colliery No. 9 of the Lehigh Coal and Navigation Company, where it measures 114 feet, as already noted, this is the greatest thickness of coal that I know of in the anthracite coal fields. These thick beds are not economically worked. In my judgment, a property containing ten beds of anthracite, each 10 feet thick, is very much more valuable to the operator than one containing a bed 100 feet thick.

Section No. 7.—Hazleton Basin, Hazleton Colliery.—Authority: Thomas S. McNair.

	Rock.	*Coal beds.*	*Total.*
1. Surface,	9′ 1″		to 9′ 1″
2. Gray slate,	34′ 2″		to 43′ 3″
3. Black slate,	2′ 2″		to 45′ 5″
4. COAL, } TWIN COAL BED,		4′ 4″	to 49′ 9″
5. Black slate, } TWIN COAL BED,	3′		to 52′ 9″
6. COAL, } TWIN COAL BED,		4′ 6″	to 57′ 3″
7. Black slate,	5″		to 57′ 8″
8. Interval, (measures not developed,)	137′ 8″		to 195′ 4″
9. Soapstone,	6′		to 201′ 4″
10. Gray slate,	10′ 2″		to 211′ 6″
11. COAL BED,		10″	to 212′ 4″
12. Black slate,	3′ 6″		to 215′ 10″
13. COAL BED,		9′ 1″	to 224′ 11″
14. Slate,	2′ 7″		to 227′ 6′
15. Sandstone,	38′ 6″		to 266′
16. COAL BED, (COAL and slate,)		4′ 4″	to 270′ 4″
17. Slate,	6′ 1″		to 276′ 5″
18. COAL BED, (slaty,)		6 6″	to 282′ 11″
19. Sandstone,	4′ 7″		to 287′ 6″
20. Fine black rock,	11′ 8″		to 299′ 2″
21. Fine gray rock,	1′ 9″		to 300′ 11″
22. Sandstone,	31′ 11″		to 332′ 10″
23. Fine gray rock,	26′ 2″		to 359′
24. Sand-slate,	51′ 10″		to 410′ 10″
25. MAMMOTH COAL BED,		32′ 11″	to 443′ 9″

26. Sand-slate, ...	11′ 8″		to 455′ 5″
27. Sandstone, ...	2′ 7″		to 458′
28. Fine conglomerate, ...	19′ 5″		to 477′ 5″
29. Fine gray rock, ...	4′ 9″		to 482′ 2″
30. Fine conglomerate, ...	1′ 7″		to 483′ 9″
31. Fine gray rock, ...	4′ 10″		to 488′ 7″
32. WHARTON COAL BED, . . .		8′ 9″	to 497′ 4″
33. Sand-slate, ...	6′ 9″		to 504′ 1″
34. Fine gray rock, ...	16′ 2″		to 520′ 3″
35. Slate, ...	2′ 7″		to 522′ 10″
36. GAMMA COAL BED, ...		2′	to 524′ 10″
37. Sand-slate, ...	4′		to 528′ 10″
38. Gray rock, ...	2′ 2″		to 531′
39. Sand-slate, ...	18′ 4″		to 549′ 4″
40. Gray rock with spar, ...	9 1″		to 558′ 5″
41. Sand-slate, ...	1′ 9″		to 560′ 2″
42. Fine conglomerate, ...	25′ 6″		to 585′ 8″
43. BUCK MOUNTAIN COAL BED,		8′ 1″	to 593′ 9″
44. Slate, ...	10″		to 594′ 7″
45. Fine gray rock, ...	14′ 10″		to 609′ 5″
Total thickness of rock, . .	528′ 1″		
" " coal beds,		81′ 4″	

This section has been constructed from data obtained in diamond drill bore-holes, shafts, and mine-workings near the middle of the Hazleton basin. It is probably as typical of the entire basin as any that could be constructed. The beds overlying the Mammoth apparently run out to a feather edge in the western part of the basin ; at least the developments in the local basin seem to indicate that this is the case. The main basin has not been sufficiently developed in this part of the section to form a general opinion. According to Mr. A. P. Berlin, Assistant Geologist, the beds underlying the Mammoth become more numerous toward the west, and the principal ones (Wharton and Buck Mountain) are more than 88 feet apart, which is the distance indicated in the above section. The Gamma bed, which occurs above the Buck Mountain, in the western end of the basin, attains a thickness of 4 feet, including 1 foot 6 inches of slate, etc.

8. *Western Middle Field.*

Section No. 8.—Shenandoah and Mahanoy Basins. Vicinity of Ellangowan Colliery.—Authority: Philadelphia and Reading Coal and Iron Company.

	Rock.		Coal Beds.		Total.	
1. Slate,	4′	8″			to 4′	8″
2. BIG TRACY COAL BED,			4′	3″	to 8′	11′
3. Dark gray slate,	32′	10″			to 41′	9″
4. Silicious rock,	18′	10″			to 60′	7″
5. Gray slate,	3′	8″			to 64′	3″
6. DIAMOND COAL BED,			6′	9″	to 71′	
7. Dark gray slate,	4′	8″			to 75′	8″
8. Slate, with iron-ore balls,	38′	9″			to 114′	5″
9. Light sandstone,	14′	4″			to 128′	9″
10. Dark gray slate,	30′				to 158′	9″
11. Conglomerate,	19′	9″			to 178′	6″
12. Dark gray slate,	10′	4″			to 188′	10″
13. LITTLE ORCHARD COAL BED,			2′	10″	to 191′	8″
14. Dark gray slate,	23′	6″			to 215′	2″
15. ORCHARD COAL BED,			10′	10″	to 226′	
16. Dark gray slate,	78′	3″			to 304′	3″
17. Dark sandstone,	16′				to 320′	3″
18. Slate, with iron-ore balls,	57′	4″			to 377′	7″
19. PRIMROSE COAL BED,			8′	4″	to 385′	11″
20. Dark gray slate, with iron-ore balls,	100′	1″			to 486′	
21. HOLMES COAL BED,			12	11″	to 498′	11″
22. Slate,	6′	1″			to 505′	
23. COAL BED,			4′	3″	to 509′	3″
24. Slate,	1′	10″			to 511′	1″
25. Silicious rock,	62′	6″			to 573′	7″
26. Slate,		4″			to 573′	11″
27. Sandstone,	56′	6″			to 630′	5″
28. Slate,	9′	5″			to 639′	10″
29. MAMMOTH COAL BED, TOP MEMBER,			12′	2″	to 652′	
30. Slate,	39′				to 691′	
31. MAMMOTH COAL BED, MIDDLE MEMBER,			7′	11″	to 698′	11″
32. Slate,	22′				to 720′	11″
33. MAMMOTH COAL BED, BOTTOM MEMBER,			15′		to 735′	11″
34. Slate,	6′	4″			to 742′	3″
35. Conglomerate,	8′				to 750′	3″
36. Slate,	6′	4″			to 756′	7″
37. SKIDMORE COAL BED,			3′	9″	to 760′	4″
38. Slate,	10′	4″			to 770′	8″
39. Sandstone,	11′				to 781′	8″
40. Slate,	3′				to 784′	8″

41. SEVEN-FOOT COAL BED, . .			6′ 6″	to 791′	2″
42. Slate, ...	8′	11″		to 800′	1″
43. Sandstone, ...	3′	9″		to 803′	10″
44. Slate, ...		8″		to 804′	6″
45. Sandstone, ...	8′	11″		to 813′	5″
46. Conglomerate, ...	42′	9″		to 856′	2″
47. Slate, ...	6′	4″		to 862′	6″
48. BUCK MOUNTAIN COAL BED,			12′ 3″	to 874′	9″
Total thickness of rock, . .	767′				
" " coal beds,			107′ 9″		

This section was compiled to accompany the map* of the mines between Mahanoy City and Shenandoah, which is being published by the Geological Survey, and is supposed to be a typical section of the coal measures of that region. There are a great many changes between these two points, both in the thickness of the coal beds and the rocks which separate them. The section would represent more particularly the stratigraphy in the vicinity of the Ellangowan colliery. Although the Big Tracy bed is placed at the top of the section, there is at least 125 feet of strata on top of it.

Section No. 9.—Shamokin Basin, Trevorton Estate—Authority: Philadelphia and Reading Coal and Iron Company.

	Rock.	Coal beds.	Total.
1. No. 16 COAL BED, ...		5′	to 5′
2. Interval, ...	63′		to 68′
3. No. 15 COAL BED, ...		5′	to 73′
4. Interval, ...	79′		to 152′
5. No. 14 COAL BED, ...		8′	to 160′
6. Interval, ...	30′		to 190′
7. LEADER OF COAL, ...		1′	to 191′
8. Interval, ...	55′		to 246′
9. No. 13 COAL BED, ...		6′	to 252′
10. Interval, ...	70′		to 322′
11. No. 12 (ORCHARD) COAL BED, . . .		4′	to 326′
12. Interval, ...	163′		to 489′
13. No. 11 (PRIMROSE) COAL BED, . . .		7′	to 496′
14. Interval, ...	100′		to 596′
15. No. 10 (HOLMES) COAL BED, ...		3′	to 599′
16. Interval, ...	85′		to 684′
17. No. 9 (MAMMOTH [TOP SPLIT]) COAL BED, ...		10′	to 694′

* Western Middle Coal Field, Mine sheet No. II.

18. Interval,	47′		to 741′
19. No. 8 (MAMMOTH [BOTTOM SPLIT]) COAL BED,		10′	to 751′
20. Interval,	112′		to 863′
21. No. 7 (SKIDMORE) COAL BED,		3′	to 866′
22. Interval,	72′		to 938′
23. No. 6 (SEVEN-FOOT) COAL BED,		7′	to 945′
24. Interval,	129′		to 1074′
25. No. 5 (BUCK MOUNTAIN) COAL BED,		22′	to 1096′
26. Interval,	130′		to 1226′
27. LEADER OF COAL,		5′	to 1231′
28. Interval,	153′		to 1384′
29. No. I (UPPER LYKENS VALLEY) COAL BED,		11′	to 1395′
30. Interval,	120′		to 1515′
31. No. 0 (LOWER LYKENS VALLEY) COAL BED,		10′	to 1525′
Total thickness of rock,	1408′		
" " coal beds,		117′	

This section has been measured by the engineers of the Philadelphia and Reading Coal and Iron Company on the Trevorton estate, which is at the extreme western limit of the Western Middle Coal Field. There are difficulties and changes in the stratigraphy of the Shamokin basin, which render it almost impossible to select any one section as typical of the entire district. Some of the sections on the property of the Mineral Railroad and Mining Company, near Shamokin, differ widely in detail from this of the Trevorton estate. This is the only section given in the series where the beds have been numbered.

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9. Southern Field.

*Section No. 10.—Panther Creek Basin, at Tamaqua.—Authority: Lehigh Coal and Navigation Company and Geological Survey.**

Upper Red Ash Group.	*Rock.*	*Coal beds.*	*Total.*
1. Interval,	216′		to 216′
2. THIRD UPPER RED ASH COAL BED,		1′	to 217′
3. Interval,	63′		to 280′
4. SECOND UPPER RED ASH COAL BED,		3′	to 283′
5. Interval,	106′		to 389′

* See Mine sheet No. III and Columnar Section sheet No. II.

6.	FIRST UPPER RED ASH COAL BED,		4′	to 393′
7.	Interval, *Lower Red Ash Group*, Interval,	158′		to 551′
8.	COAL BED, } SECOND TWIN BEDS,		2′	to 553′
9.	Interval, } SECOND TWIN BEDS,	13′		to 566′
10.	COAL BED, } SECOND TWIN BEDS,		2′	to 568′
11.	Interval,	128′		to 696′
12.	COAL BED, } FIRST TWIN BEDS,		2′	to 698′
13.	Interval, } FIRST TWIN BEDS,	13′		to 711′
14.	COAL BED, } FIRST TWIN BEDS,		2	to 713′
15.	Interval,	38′		to 751′
16.	JOCK COAL BED,		7′	to 758′
17.	Interval,	92′		to 850′
18.	WASHINGTON COAL BED,		3′	to 853′
19.	Interval,	84′		to 937′
20.	G, OR UPPER RED ASH, COAL BED,		6′	to 943′
21.	Interval,	46′		to 989′
22.	BONY COAL BED,		4′	to 993′
23.	Interval,	55′		to 1048′
24.	F, OR LOWER RED ASH, COAL BED,		10′	to 1058′
	White Ash Group.			
25.	Interval,	211′		to 1269′
26.	E COAL BED, } MAMMOTH COAL BED.		24′	to 1293′
27.	Interval, } MAMMOTH COAL BED.	45′		to 1338′
28.	CROSS-CUT COAL BED, } MAMMOTH COAL BED.		5′	to 1343′
29.	Interval, } MAMMOTH COAL BED.	48′		to 1391′
30.	D COAL BED, } MAMMOTH COAL BED.		12′	to 1403′
31.	Interval,	122′		to 1525′
32.	C COAL BED,		8′	to 1533′
33.	Interval,	175′		to 1708′
34.	COAL BED,		—	
35.	Interval,	55′		to 1763
36.	B COAL BED,		9′	to 1772′
37.	Interval,	115′		to 1887′
38.	A COAL BED,		16	to 1903′
	Lykens Valley Group.			
39.	Interval,	240′		to 2143′
40.	UPPER LYKENS VALLEY COAL BED,		6′	to 2149′
41.	Interval,	145′		to 2294′
42.	LOWER LYKENS VALLEY COAL BED,		?	
	Total thickness of rock,	2168′		
	" " coal beds,		126′	

This section is unlike the section given for the Pottsville basin, inasmuch as it represents the succession of strata in one locality. The measurements were made in and about the mines north of Tamaqua, on the east side of the Little Schuylkill river, and through the Locust Mountain gap, where the entire series of strata, represented in the section, dip away from the Locust Mountain south-west, toward the town of Tamaqua, to a point on the river midway between Elm and Vine streets. Here a reverse dip on the south side of the Panther Creek basin is encountered, the center of the basin or synclinal being located at this point. In other words, if a diamond drill-hole should be started at the point indicated, and drilled in a direction (N. 18° 30′ W.) perpendicular to the strike of the rocks and at the same time perpendicular to the dip or pitch of the beds, or at an angle of 30 degrees with the horizon, the section here given should show the coal beds and their distances apart, as they would be found in the drill-hole.*

Section No. 11.—Pottsville Basin—Authority: Philadelphia and Reading Coal and Iron Company.

Belmont Estate, east of Pottsville.	*Rock.*	*Coal beds.*	*Total.*
1. Lewis coal bed,		8′	to 8′
2. Interval,	210′		to 218′
3. Spohn coal bed,		8′	to 226′
4. Interval,	210′		to 436′
5. Palmer coal bed,		3′	to 439′
6. Interval,	263′		to 702′
7. Charlie Pott coal bed,		3′	to 705′
8. Interval,	78′		to 783′
9 Clarkson coal bed,		7′	to 790′
10. Interval,	83′		to 873′
11. Selkirk coal bed,		7′	to 880′
12. Interval,	120′		to 1000′
13. Leader of coal,		3′	to 1003′
14. Interval,	45′		to 1048′
In vicinity of Pottsville Shafts.			
15. Peach Mountain coal bed,		5′	to 1053′
16. Interval,	60′		to 1113′
17. Coal bed,		3′	to 1116′

* The coal beds at Tamaqua were originally named from A to T; A being the first bed which was known at that time in the Locust Mountain gap going south, and T being the most southern bed which was known to exist in the Sharp Mountain gap. Although it was a well-recognized fact by those who had some understanding of the geology of the Tamaqua section, that the same bed at different outcrops and in different basins was assigned different letters, yet the idea that there were actually 20 individual coal beds, one above the other, at Tamaqua, was quite prevalent. My attention was only recently called to this fact by an engineer in the region, who thought that even now, there were many persons in the coal region who believed in the existence of all of these separate beds.

18. Interval,	58′		to 1174′
19. Little Tracy coal bed,		6′	to 1180′
20. Interval,	198′		to 1378′
21. Coal bed,		2′	to 1380′
22. Interval,	40′		to 1420′
23. Little Diamond coal bed,		3′	to 1423′
24. Interval,	122′		to 1545′
25. Diamond coal bed,		6′	to 1551′
26. Interval,	158′		to 1709′
27. Little Orchard coal bed,		3′	to 1712′
28. Interval,	25′		to 1737′
29. Orchard coal bed,		4′	to 1741′
30. Interval,	190′		to 1931′
31. Primrose coal bed,		8′	to 1939′
32. Interval,	91′		to 2030′
33. Holmes coal bed,		4′	to 2034′
34. Interval,	70′		to 2104′
35. Leader of coal,		4′	to 2108′
36. Interval,	140′		to 2248′
37. Mammoth (Top split) coal bed,		7′	to 2255′
38. Interval,	15′		to 2270′
39. Mammoth (Bottom split) coal bed		25′	to 2295′
40. Interval,	60′		to 2355′
41. Skidmore coal bed,		8′	to 2363′
42. Interval,	72′		to 2435′
43. Seven-Foot coal bed,		3′	to 2438′
44. Interval,	80′		to 2518′
45. Leader of coal,		—′	to —′
46. Interval,	25′		to 2543′
47. Leader of coal,		2′	to 2545′
48. Interval,	25′		to 2570′
49. Buck Mountain coal bed.		8′	to 2578′
Eckert Colliery, Tremont.			
50. Interval,	554′		to 3132′
51. Coal bed,		2′	to 3134′
52. Interval,	50′		to 3184′
53. Coal bed,		2′	to 3186′
54. Interval,	55′		to 3241′
55. Lykens Valley coal bed,		10′	to 3251′
Total thickness of rock,	3097′		
" " coal beds,		154′	

The upper part of this section, above the Peach Mountain bed, is located about 14 miles (air-line) east of Tremont, at which point the lower part of the section below the Buck Mountain bed has been measured; while the section between these two beds, (Peach Mountain and Buck Mountain), measured in the vicinity of the Pottsville shafts, is between Tremont and the Belmont estate—in fact, but a short distance west of the latter locality. The entire section, as it has been compiled and reported to me by Mr. Bard Wells, Assistant Geologist, may be said to represent fairly the succession and thickness of the strata of the Southern Field, but does not necessarily represent what would be absolutely found in any one place by commencing to drill in the Lewis bed and piercing the entire series down to the Lykens Valley coal bed.

The names assigned to the beds in this section are not universally accepted, by the local engineers and geologists in the Southern Field. Other systems of naming have been reported which may ultimately prove preferable to the above. A discussion of this subject is deferred until the final report.

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10. Difficulties of identification.

No attempt has yet been made by the Geological Survey to systematize these sections. In fact, I believe it is quite impossible to do so. A careful study, of the information contained in these sections, cannot fail to show the inconsistencies in naming the beds, and the difficulties, which at present seem almost insurmountable, in the way of either identifying the beds over the entire region, or of proposing any plan of naming which would not lead to errors.

The following may be noted as a few of the inconsistencies shown on the accompanying sheet of sections.*

In Section No. 10 the F, or first bed above the Mammoth, is frequently called the Primrose bed between Mauch Chunk and Tamaqua, while in the western part of the Southern Coal Field and in the Western Middle Coal Field, the second bed above the Mammoth is generally called the Primrose; the first bed above the Mammoth, which is worked in a number of localities in these basins, being known as the Holmes bed.

The B bed and Buck Mountain bed are generally consid-

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* Miscellaneous sheet No. II.

ered to be the same. The name Buck Mountain has been generally assigned to the lowest workable coal bed in the region, exclusive of the Lykens Valley beds. Along the Locust Mountain, north of Tamaqua, however, there is a coal bed (called A) 16 feet thick,* 115 feet under the bed which has been named B or Buck Mountain. This A bed has been extensively worked here, and has produced good coal.

At Tamaqua the bottom bench or split of the Mammoth bed is named D. At Nanticoke (Section No. 5) the Twin bed, which is 120 feet under the Bennett Forge or E bed, (which at this point is considered to be the bottom split of the Mammoth,) is sometimes named D. At Wilkes-Barre (Section No. 4) the D bed is the third under the Baltimore or Mammoth, and 222 feet below it. In the Lackawanna basin (Section No. 3) the D bed is the third bed above the Big bed, which is supposed to be the Mammoth, with an interval between the two of 258 feet. In the former cases the beds are lettered from the bottom up; in the latter, from the top down. In this instance the inconsistency in naming may be readily understood, and need not occasion errors in the comparison of sections, if it is known for a certainty in a written section whether the highest or lowest geological stratum is recorded first. As there is no general rule in recording a written section, great difficulty is sometimes experienced in ascertaining which is top and which is bottom.

The total thickness of coal which can be economically mined in each basin, with the present system of mining, will not be as great as the total coal given in feet for each section, as most coal beds contain, interlocked with the different coal benches, layers of slate and poor bony coal; in some places the total thickness of coal given for the section includes beds as low as one foot in thickness; at present it is not generally considered profitable to mine an anthracite coal bed which is under four or five feet thick. The variability of the thickness of the beds is such, how-

*The average thickness of this bed here is probably about 6 feet.

ever, that in many cases the total coal which can be mined from any one bed may be greater than that given,* while in special instances the thickness assigned to the workable beds may be excessive.

Panther Creek Model.

A model of the floor of the Mammoth coal bed in the Panther Creek Valley, as shown by the contour curves on Mine sheets Nos. I, II and III, was constructed by Messrs. E. B. and O. B. Harden, on horizontal and vertical scales of 800 feet to 1 inch, respectively. This model was made by a method originally designed by Mr. John Hy. Harden. Every other contour curve (100 feet apart) was traced independently, on a board $\frac{1}{8}$ inch thick, and was then cut out by a jig-saw. These boards were afterwards piled up, one upon another, so that the edge of each board, along the contour curve, would be perpendicularly projected into the position of the contour curve on the map. The reëntering angles of this wooden model were then filled out with modelling wax and a negative and afterwards a plaster of Paris cast made. A photo-lithograph was made of the positive cast on a reduced scale of about 2,400 feet to 1 inch, this is shown by the accompanying Plate No. IV.

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*The Mammoth bed in the Black Creek Basin (Jeddo section) is given as twenty-seven feet thick. This bed, as has been noted, is worked by Calvin Pardee & Co., in the Hollywood quarries, where it sometimes measures as much as one hundred and two feet. The coal is obtained here by stripping off everything above the surface of the bed and quarrying the coal in an open cut.

SOUTHERN COAL FIELD — PANTHER CREEK BASIN

VIEW OF A PLASTER MODEL SHOWING THE PLICATIONS OF THE MAMMOTH BED BETWEEN TAMAQUA AND MAUCH CHUNK

(FROM A PHOTOGRAPH)

MODEL CONSTRUCTED BY E. B. HARDEN

FIRST REPORT OF THE PROGRESS

OF THE

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA,

IN THE

ANTHRACITE DISTRICT.

APPENDIX A.

DETERMINATION OF THE LATITUDE AND LONGITUDE OF WILKES BARRE IN LUZERNE COUNTY AND OF POTTSVILLE IN SCHUYLKILL COUNTY,

BY PROFESSOR C. L. DOOLITTLE.

The determination of the geographical co-ordinates of Wilkes Barre and Pottsville, the details of which are given in the following pages, was undertaken in August, 1881, at the request of Mr. Chas. A. Ashburner, Geologist in charge of the Anthracite Survey, the object being to furnish definite points of reference for the maps of the Anthracite coal regions.

The first observations were made at Wilkes Barre on the night of August 10th, when twenty-two pairs of stars were observed with the Zenith Telescope. On the 12th twenty-six pairs were observed. This was sufficient for as accurate a determination of the Latitude as was contemplated. Owing to unexpected delay in obtaining the use of the wires of the Western Union Telegraph Company for the longitude signals this part of the work was deferred until after the observations at Pottsville were completed. The instruments were accordingly removed to the latter place, all necessary arrangements having been made. Four nights proved sufficient for obtaining sixty-four pairs of stars for Latitude and three series of Longitude signals. Signals were finally exchanged on two nights for determining the Longitude of Wilkes Barre, but it was not until October 6th that the last of these were obtained.

I wish to express my thanks to Messrs. G. H. Grace, Superintendent of the Western Union Telegraph lines at Philipsburg; J. E. Zeublin, Superintendent at Philadelphia, and O. W. Stager, Superintendent of the Philadelphia, Reading and Pottsville Telegraph Company for their kind coöperation in furthering the work. Also to the telegraph operators at Wilkes Barre and Pottsville for their efficient and courteous assistance.

The Telegraph companies with their customary liberality in such matters gave the free use of their wires for sending the signals and also for a large number of messages incident thereto.

Instruments.

The instruments employed were a Mean Time chronometer, Transit, and Zenith telescope, the two latter being the property of the Lehigh University. The chronometer was loaned to me by Messrs. T. S. and J. D. Negus, of New York. The performance of the instrument was in all respects satisfactory.

The Zenith Telescope.

This is a somewhat antiquated instrument purchased some years ago from the U. S. Coast Survey, where it had been superseded by more perfect instruments. The makers were E. & G. W. Blunt, of New York. After it came into the possession of the University it was repaired and fitted with a new level by Edw. Kahler, of Washington, D. C. The telescope has an aperture of 3 inches. The focal length is 41 inches. The eye piece magnifies 75 diameters.

The Micrometer.

The value of one revolution of the micrometer screw which was used was determined from transits of λ Ursæ Minoris and 51 Cephei observed at elongation. The work was done somewhat thoroughly during the years 1875, 1876, and 1877, and I did not think it necessary to make a new determination on this occasion. No account was taken of the temperature coefficient—its use with an instrument of this character being deemed an excess of refinement. The individual values, with time of observation, are as follows :

Star.	Date.	Elongation.	Micrometer value.	v
			″	
λ Ursæ Minoris,	1875, Dec. 22	W	50.504	+54
"	Dec. 27	W	50.495	+45
"	1876, April 19	E	50.473	+23
"	Aug. 15	W	50.444	— 6
"	1877, Oct. 5	W	50.445	— 5
51 Cephei,	1875, Dec. 27	E	50.450	0
"	1876, April 19	W	50.403	—47
"	1876, Aug. 15	E	50.453	+ 3
"	1877, Oct. 5	E	50.385	—65

Mean of nine values, 50″.450 ± 009.

The Level.

The value of one division of the level was determined by means of the mural circle of the U. S. Naval Observatory. The circle is read by means of six microscopes, four of which were used. The following are the individual values :

No.	Value of 1 division.	v.	No.	Value of 1 division.	v.	No.	Value of 1 division.	v.
1	1″.10	4	6	1″.04	2	11	1″.30	24
2	1.16	10	7	1.22	16	12	1.02	4
3	.88	18	8	1.00	6	13	.93	13
4	1.10	4	9	1.11	5	14	1.08	2
5	.98	8	10	.96	10	15	1.01	5

Mean of 15 values, 1″.059 ± 019.

The range is larger than is desirable, and a considerable part of the error in the individual determinations of the latitude is no doubt due to this cause.

The Transit Instrument.

This instrument was made by Messrs. Stackpole & Bro., of New York. The aperture of telescope is 2 inches, focal length 26 in., length of axis 16 in. The eye piece magnifies 40 diameters. The reticule contains 15 threads, arranged in groups of 5 each. Only the middle group has ever been used for observation.

The striding level was made by Kahler, of Washington. The value of one division was determined by a level trier kindly loaned me by Prof. Harkness, of the U. S. Observatory. The individual values are as follows:

1	2″.675	4	2″.525	7	2″.493	10	2″.633	13	2″.639
2	2.568	5	2.605	8	2.581	11	2.770	14	2.591
3	2.552	6	2.615	9	2.635	12	2.670	15	2.610

Mean of 15 determinations, 2″.611 = .174*s*.

Equatorial Intervals of Threads.

At Pottsville the transit was used on the nights of August 20th, 22nd, and 23d. The instrument was not dismounted until the work was completed. The equatorial intervals determined from all transits suitable for the purpose observed on these three nights, were as follows:

s
I+32.604
II+16.129
III+ .018
IV—16.283
V—32.474

These values are the mean of twenty determinations.

At Wilkes Barre the longitude determinations were made on the nights of September 30th and October 6th. Between these dates the instrument was dismounted. The thread intervals were as follows:

September 30.	*October 6.*
s	*s*
I+32.543	I+32.636
II+16.181	II+16.184
III+ .129	III+ .035
IV—16.296	IV—16.350
V—32.551	V—32.496

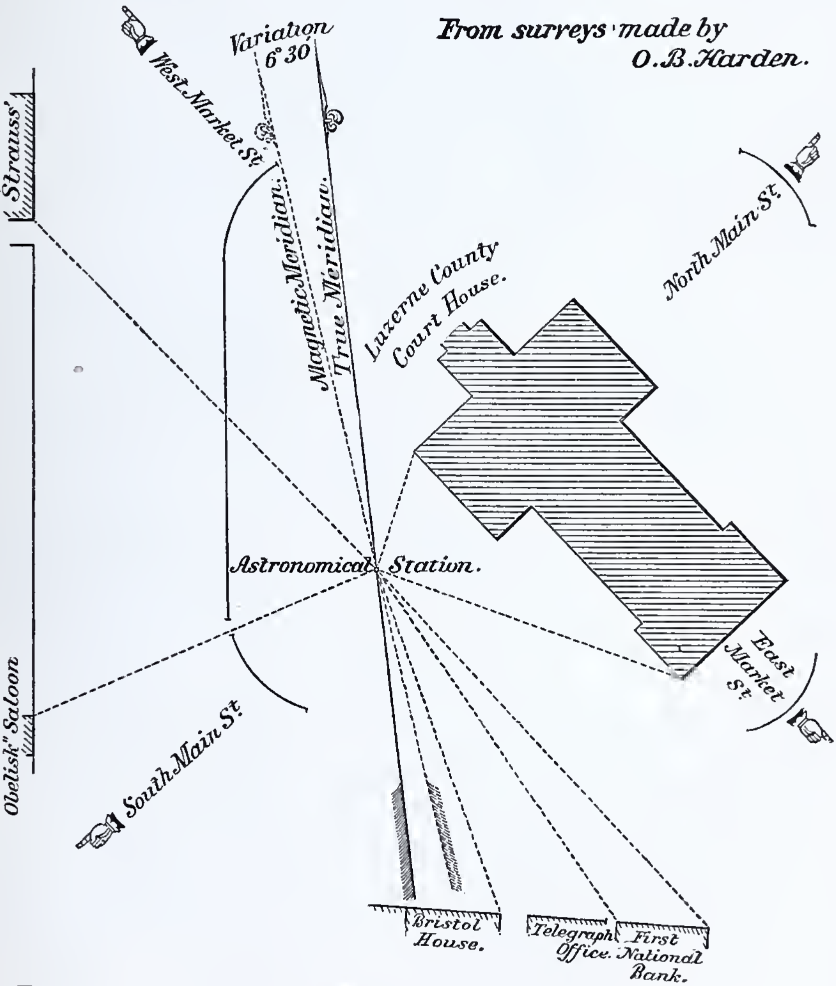
The first of these is the mean of 9 determinations and the second of 8. They were only required in reducing imperfect transits, the mean of the threads being used in other cases.

References of Wilkes Barre Astronomical Station.

Courses referred to True Meridian. Distances in Feet.

Station to Court House,	(N. W. Corner)	N. 24° 54′ E.	56.0
" " "	(S. W. ")	S. 63° 38′ E.	148.6
" " First National Bank,	(N. E. ")	S. 36° 21′ E.	224.5
" " " " "	(N. W. ")	S. 27° 54′ E.	197.4
" " Bristol House,	(N. E. ")	S. 13° 18′ E.	169.2
" " "Obelisk" Saloon,	(N. E. ")	S. 73° 34′ W.	171.9
" " Strauss' Store,	(S. E. ")	N. 37° 45′ W.	224.7

From surveys made by
O. B. Harden.



Inscriptions on Granite Monument marking Wilkes Barre Astronomical Station.

North side.	West side.	South side.	East side.
Erected August, 1881. L. C. Darte. Stephen Turnbach. J. D. Harris. County Commissioners. S. A. Whitebread, Clerk.	Second Geological Survey of Pennsylvania.	Latitude 41 degrees 14 minutes 40.4 seconds.	Longitude East from Washington 1 degree 10 minutes 4.6 seconds.*

50 40 30 20 10 0 100 200 300 FEET
10 0 10 20 30 40 50 60 70 80 90 METERS

* See pages 274 and 275. AA.

Observatory at Wilkes Barre.

This consisted of a shed of rough boards 10 feet long by 7 feet, 6 inches wide. Two posts were planted in the ground to a depth of 3 feet, on top of which the instruments were mounted. These were solid logs sawed off square, the easterly one, on which was mounted the transit, being 18 inches in diameter, the other 26. The structure was erected in the court house square to the east of the court house building. The exact position of the transit station is shown on the accompanying map. (See page 247). The post which carried the transit has been replaced by a monument of Quincy granite, erected by the County Commissioners.

The situation being in the busiest part of the city, was subject to the annoyance caused by the constant passage of vehicles on the streets until a late hour at night. The disturbance of the instruments from this cause was sometimes very considerable.

Observatory at Pottsville.

This was placed in the grounds of the county jail. The transit station is marked by a granite post, the location of which is shown by the accompanying map. (See page 249).

It was similar to that at Wilkes Barre, except that the instruments were mounted on a sort of tripod, formed by planting in the ground three posts 4×6 inches. On top of these was spiked a plank of seasoned oak 3 inches in thickness. Pieces of inch board were nailed across from post to post for the purpose of stiffening the whole. This arrangement was less satisfactory than a solid log, but nothing better could be provided at the time without considerable delay and expense.

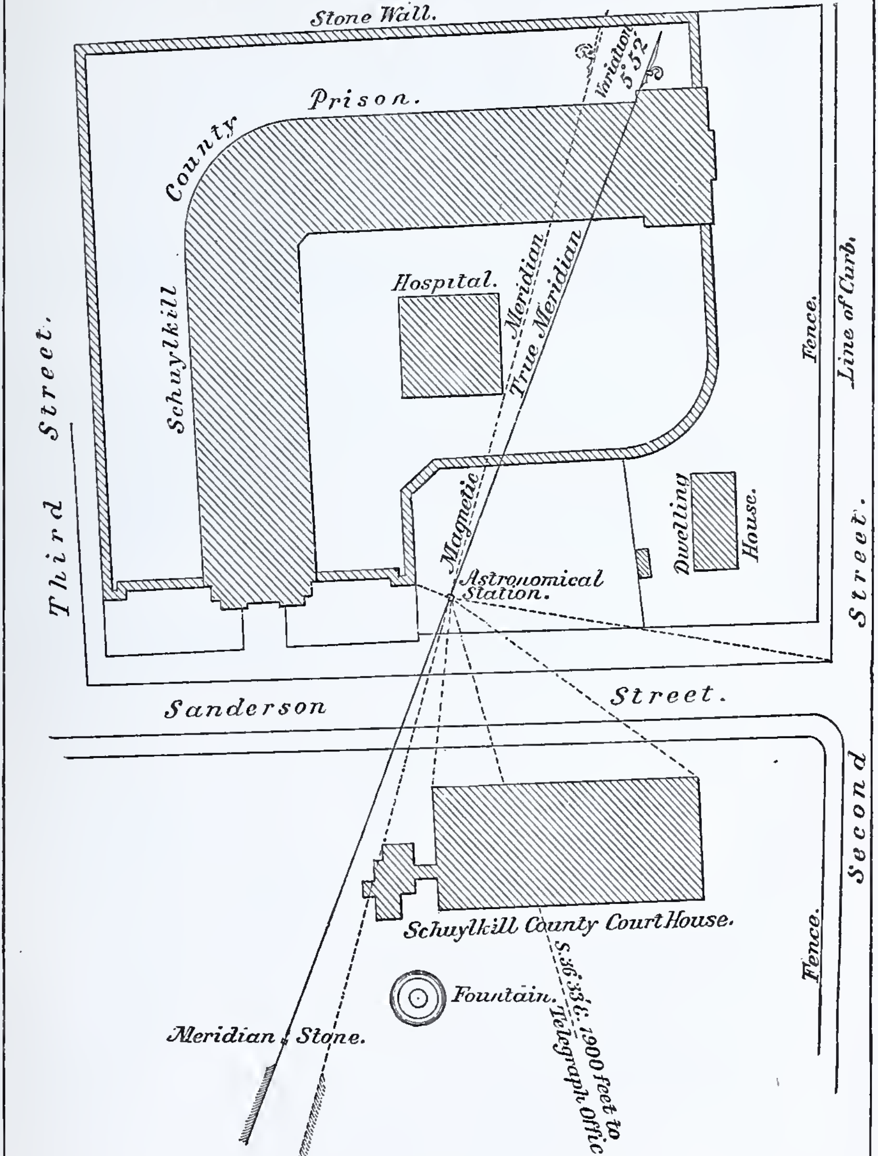
The Longitude.

The transits were observed by the eye and ear method. As the chronometer was regulated for mean solar time I had my watch adjusted to run on sidereal time for convenience in finding the star. The stars were observed in groups consisting, as far as practicable, of six stars each,

References of Pottsville Astronomical Station.

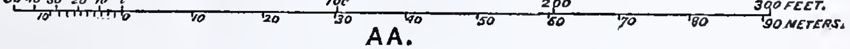
Courses referred to True Meridian. Distances in Feet.

Station to Court House	(N.W. Corner,)	S. 14° 44′ E.	87.4
" " "	(N.E. ")	S 74° 56′ E.	141.1
" " Curb at Sanderson & 2nd Sts.	(N.W. ")	N. 78° 36′ E.	177.6
" " Jail Wall	(S.E. ")	N. 89° 17′ W.	16.1



Distance along True Meridian, between Astronomical Station in Prison Yard and Meridian Stone in Court House Yard 219.29 feet.

O.B.H.



viz: two circumpolar stars,—one at upper and one at lower culmination,—two equatorial and two zenith stars. Two groups were observed,—one in each position of the axis,—when the chronometer was taken to the telegraph office and the longitude signals exchanged, as will be explained later. After this the chronometer was brought back to the observatory and two more groups observed precisely as before. At Wilkes Barre it will be seen a few more stars were observed than at Pottsville, but otherwise the process was alike at both points.

At Pottsville the observatory was distant from the telegraph office 1900 feet. At Wilkes Barre the distance was 200 feet.

Reduction of Observations.

Let α & δ be the Right Ascension and Declination of any star,

Φ—the Latitude of Station,

ΔT—the chronometer correction on sidereal time at chronometer time T,

x—the hourly rate of the chronometer,

a—the azimuth of instrument,

b—the level correction,

c—the collimation constant,

$$A=\frac{\sin(\Phi-\delta)}{\cos\delta} \qquad B=\frac{\cos(\Phi-\delta)}{\cos\delta} \qquad C=\frac{1}{\cos\delta}$$

Then $Aa+Cc+\Delta T+(T'-T)\,x+u=0$

Where T' is the chronometer time of observation

$u=T'+Bb-\alpha$

Each star gives an equation of the above form for determining the unknown quantities a, c, ΔT & x.

A preliminary reduction showed that only on the night of October 6th could the observations be well represented by assuming the azimuth to remain constant throughout the entire series. Accordingly, a new reduction was made in which different values were determined from the observations before and after the exchange of signals. The values of the azimuth and collimation resulting from the solution of the normal equations were then regarded as final and a new series of equations formed for determining the chronometer correction and rate. In these latter equations only those stars were used which culminated comparatively near the zenith. Owing to the instability of the azimuth this result is no doubt the best available.

Stars Observed.

Only Nautical Almanac stars were used with the single exception of 37 Cassiopeæ, observed by mistake for 38 Cassiopeæ, owing to an error of 10° in setting the finding circle. Preference was given to stars which are reduced to apparent place in the volume for 1881. Where these were not sufficiently numerous the deficiency was supplied by stars taken from the volume of 1882 not reduced to apparent place. These were reduced by the formula

$$\alpha = \alpha_0 + f + \tfrac{1}{15} g \sin (G + \alpha) \tan \delta + \tfrac{1}{15} h \sin (H + \alpha) \sec \delta$$

See Nautical Almanac, p. 258.

The details of the observations at Pottsville with data for reduction immediately follow. They will require no further explanation.

1881, Aug. 20. *Pottsville.*

$\triangle T$ Determined for Chronometer time 10*h*. 40*m*.

STAR.	Lamp.	No. of threads.	Mean of threads.	*Aa.*	*Aa'.*	*Bb.*	*Cc'.*	Acceleration.	Corrected transit.	Right Ascension.	N.	O-C.
			h. m. s.						*h. m. s.*	*h. m. s.*	*h. m. s.*	
50 Draconis,	E	3	8 48 15.23	. . . .	. . . .	+ .28	— .06	—18.36	8 47 57.09	18 50 14.13	10 2 17.04	
γ Lyræ.	E	4	8 52 33.58	. . . .	. . . .	+ .09	— .02	—17.65	8 52 16.00	18 54 32.92	16.92	+23
25 Camel, ... *sp.*	E	5	9 4 1.26	. . . .	. . . .	— .26	+ .12	—15.77	9 3 45.35	7 6 2.65	17.30	
θ Lyræ,	E	4	9 10 15 69	. . . .	. . . .	+ .06	— .02	—14.74	9 10 0.99	19 12 17.62	16.63	— 4
β Cygni,	E	5	9 23 54.60	. . . .	. . . .	+ .04	— .02	—12.50	9 23 42.12	19 25 58.97	16.85	+ 8
κ Aquilæ,	E	5	9 28 28.32	. . . .	. . . .	+ .02	— .02	—11.75	9 28 16.57	19 30 33.62	17.05	
β Sagittæ,	W	5	9 33 41.32	. . . .	. . . .	+ .13	— .02	—10.89	9 33 30.54	19 35 46.08	15.54	—24
ε Draconis,	W	5	9 46 32.94	. . . .	. . . .	+ .32	— .05	— 8.78	9 46 24.43	19 48 37.34	12.91	
γ Sagittæ,	W	5	9 51 23.94	. . . .	. . . .	+ .11	— .02	— 7.98	9 51 16.05	19 53 31.78	15.73	— 3
3 Urs. Maj., . . . *sp.*	W	5	9 58 47.36	. . . .	. . . .	— .10	+ .04	— 6.77	9 58 40.53	8 0 59.96	19.43	
ο Cygni,	W	5	10 7 46.76	. . . .	. . . .	+ .13	— .02	— 5.29	10 7 41.58	20 9 56.74	15.16	— 1
ζ Capricorni,	W	5	11 17 35.04	. . . .	. . . .	+ .09	— .02	+ 6.17	11 17 41.28	21 19 56.98	15.70	
β Aquarii,	W	5	11 22 58.94	. . . .	. . . .	+ .13	— .02	+ 7.06	11 23 6.11	21 25 22.05	15.94	
74 Cygni,	W	4	11 29 51.13	. . . .	. . . .	+ .24	— .02	+ 8.19	11 29 59.54	21 32 14.95	15.41	— 6
ε Pegasi,	W	5	11 35 59.62	. . . .	. . . .	+ .16	— .02	+ 9.20	11 36 8.96	21 38 24.74	15.78	— 8
π^2 Cygni,	W	5	11 40 2.80	. . . .	. . . .	+ .28	— .02	+ 9.86	11 40 12.92	21 42 28.14	15.22	— 3
μ Capricorni,	W	5	11 44 26.50	. . . .	. . . .	+ .11	— .02	+10.59	11 44 37.18	21 46 52.97	15.79	
α Aquarii,	W	3	11 57 15.95	. . . .	. . . .	+ .14	— .02	+12.69	11 57 28.76	21 59 44.63	15.87	
π Pegasi,	W	5	12 2 17.14	. . . .	. . . .	+ .23	— .02	+13.52	12 2 30.87	22 4 46.40	15.53	—10
32 Urs. Maj., . . *sp.*	W	5	12 6 51.84	. . . .	. . . .	— .13	+ .04	+14.27	12 7 6.02	10 9 23.63	17.61	
π Aquarii,	E	5	12 16 43.10	. . . .	. . . .	+ .14	— .02	+15.89	12 16 59.11	22 19 16.30	17.19	+20
9 Draconis, ... *sp.*	E	5	12 22 23.66	. . . .	. . . .	— .35	+ .07	+16.82	12 22 40.20	10 24 56.17	15.97	

10 Lacertæ,	E	5	12 31 24.34	....	....	+ .22	− 02	+18.30	12 31 42.84	22 33 59.73	16.89	+01
λ Pegasi,	E	5	12 38 15.70	....	....	+ .18	− .02	+19.43	12 38 35.29	22 40 52.26	16.97	+05
ι Cephei,	E	5	12 42 54.88	....	....	+ .37	− .04	+20.19	12 43 15.40	22 45 32.11	16.71	
α Pis. Aus.,	E	5	12 48 30.54	....	....	+ .06	− .02	+21.11	12 48 51.69	22 51 8.98	10 2 17.29	

First Normal Equations.

$$57.391a \quad - 47.608c - 9.102x + 7.36t - 20.530 = 0$$
$$- 25.341a' - 14.117c + 15.281x + 10.91t - 4.812 = 0$$
$$- 47.608a - 14.117a' + 147.641c + 2.875x - 6.95t - 32.490 = 0$$
$$- 9.102a + 15.281a' + 2.875c + 49.661x + 7.38t - 1.857 = 0$$
$$7.360a + 10.910a' - 6.950c + 7.380x + 26.00t - 8.430 = 0$$

s.

a = + .781

a' = + .455

c = + .518

Second Normal Equations.

$$13.000t + 2.550x - 1.060 = 0$$
$$2.550t + 23.614x - 1.854 = 0$$

$t = +.0678 \pm 0241$

$x = +.0712$

Assumed $\triangle T = 10h.\ 2m.\ 16s.$

Therefore $\triangle T = 10h.\ 2m.\ 16.068s. \pm 024.$

1881, Aug. 22.

Pottsville.

Assumed, $a = -\overset{s}{1.5}$
$a' = -2.7$
$c = +\ .5$

$\triangle T$ Determined at Chronometer time 9*h.* 35*m.*

STAR.	Lamp.	No. of threads.	Mean of threads.	*Aa.*	*Aa'.*	*Bb.*	*Cc'.*	Acceleration.	Corrected transit.	Right ascension.	N.	O–C.
			h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	
θ Ophiuchi, ...	W	5	7 5 12.24	—1.50	. . . .	.10	— .57	—24.61	7 4 45.66	17 14 46.29	10 9 60.63	
α Ophiuchi, ...	W	4	7 19 51.16	— .72	. . . .	.18	— .53	—22.20	7 19 27.89	17 29 27.96	60.07	—.04
ι Herculis, ...	W	5	7 26 30.30	+ .21	. . . .	.28	— .74	—21.11	7 26 8.94	17 36 8.92	59.98	—.20
γ Draconis, ...	W	5	7 44 11.16	+ .45	. . . .	.29	— .83	—18.20	7 43 52.87	17 53 53.01	60.14	—.07
22 Camel, ... *sp.*	W	5	7 56 6.78	—3.99	. . . .	— .17	1.47	—16.24	7 55 47.85	6 5 48.21	60.36	
η Serpentis, ...	E	3	8 5 27.73	—1.04	. . . .	.18	.48	—14.71	8 5 12.64	18 15 13.01	60.37	
κ Draconis, ...	E	5	8 13 21.16	+2.67	. . . .	.70	1.63	—13.41	8 13 12.75	18 23 13.56	60.81	
α Lyræ, ...	E	5	8 23 8.32	— .06	. . . .	.30	.62	—11.81	8 22 57.37	18 32 57.67	60.30	—.04
β Lyræ, ...	E	5	8 35 53.02	— .24	. . . .	.28	.58	— 9.71	8 35 43.93	18 45 44.48	60.55	+.22
50 Draconis, ...	E	5	8 40 16.38	+3.36	. . . .	.74	1.91	— 8.99	8 40 13.40	18 50 13.97	60.57	
γ Lyræ, ...	E	5	8 44 40.04	— .25	. . . .	.26	.58	— 8.27	8 44 32.36	18 54 32.89	60.53	+.20
25 Camel, . . *sp.*	E	3	8 56 25.05	—9.78	. . . .	— .95	—3.78	— 6.34	8 56 4.20	19 6 2.96	58.76	
Groombridge 3241, .	E	5	10 20 20.04	. . . .	+4.59	1.55	1.57	+ 7.45	10 20 35.20	20 30 34.57	59.37	
α Cygni, ...	E	5	10 27 15.60	. . . .	+ .27	.73	.69	8.59	10 27 25.88	20 37 26.37	60.49	+.08
ε Cygni, ...	E	5	10 31 17.26	. . . .	— .40	.57	.58	9.25	10 31 27.26	20 41 27.70	60.44	—.03
ν Cygni, ...	E	5	10 42 35.34	. . . .	— .00	.58	.64	11.10	10 42 47.66	20 52 48.16	60.50	+.05
σ^2 Urs Maj., . . . *sp.*	E	5	10 49 51.30	. . . .	—6 72	— .33	—1.27	12.30	10 49 55.28	8 59 56.09	60.81	
ζ Cygni, ...	E	5	10 57 41.82	. . . .	— .59	.41	.56	13.59	10 57 55.79	21 7 56.34	60.55	+.04

α Cephei, ...	W	5	11 5 31.64	. . . .	+2.11	.94	—1.10	14.87	11 5 48.46	21 15 48.65	60.19	
d Urs Maj., . . . *sp.*	W	5	11 13 46.68	. . . .	—7.48	— .52	1.54	16.23	11 13 56.45	9 23 57.36	60.91	
74 Cygni, ...	W	5	11 21 57.12	. . . .	— .05	.64	— .67	17.57	11 22 14.61	21 32 14.95	60.34	—.01
ε Pegasi, ...	W	5	11 28 7.38	. . . .	—1.43	.44	— .53	18.58	11 28 24.44	21 38 24.74	60.30	—.22
μ Capricorni, ...	W	4	11 36 35.27	. . . .	—2.27	.30	— .53	+19.97	11 36 52.74	21 46 52.98	10 9 60.24	

First Normal Equations.

$$59.645\delta a + \quad - 57.879\delta c' - 8.204\,x + 7.260\delta t + 8.776 = 0$$
$$18.438\delta a' - 3.304\delta c + 8.314\,x + 4.440\delta t - 5.967 = 0$$
$$-57.879\delta a - 3.304\delta a' - 149.287\delta c - 1.952\,x + 5.050\delta t - 16.387 = 0$$
$$-8.204\delta a + 8.314\delta a' - 1.952\delta c + 53.278\,x - 2.620\delta t - 882 = 0$$
$$7.260\delta a + 4.440\delta a + 5.050\delta c - 2.620\,x + 23.000\delta t - 7.210 = 0$$

$\delta a = -.135$ Therefore $a = -1.635$

$\delta a' = +.278$ $a' = -2.422$

$\delta c = +.052$ $c = +.552$

Second Normal Equations.

$$12.00\delta t - 1.27\,x - .290 = 0$$
$$-1.27\delta t + 27.732\,x - 1.238 = 0$$
$$\delta t = +.029 \pm .027$$
$$x = +.046$$

Assumed $\triangle T = +10h.\ 10m.\ 00.3s.$

Therefore $\triangle T = 10h.\ 10m.\ 00.329s \pm 027.$

1881, Aug. 23.

Pottsville.

Assumed $a = -1.6^s$
$a = -2.5$
$c = +.55$

ΔT Determined at chronometer time 9*h*. 25*m*.

STAR.	Lamp.	No. of threads.	Mean of threads.	*Aa.*	*Aa*	*Bb*	*Cc'*	Acceleration.	Corrected transit.	Right ascension.	N.	O–C.
			h. m. s.						*h. m. s.*	*h. m. s.*	*h. m. s.*	
ι Herculis, ...	E	5	7 22 31.10	+ .22	. . . .	+ .17	+ .77	—20.12	7 22 12.14	17 36 8.89	10 13 56.75	+16
ψ' Draconis, ...	E	5	7 30 21.72	+ 2.74	. . . .	+ .20	+ 1.72	—18.83	7 30 7.55	17 44 4.20	56.65	
γ Draconis, ...	E	5	7 40 12.32	+ .48	. . . .	+ .04	+ .86	—17.22	7 39 56.48	17 53 52.99	56.51	—12
22 Camel, ... *sp.*	E	5	7 52 13.46	— 4.26	. . . .	+ .02	— 1.51	—15.24	7 51 52.47	6 5 48.29	55.82	
η Serpentis, ...	E	5	8 1 30.90	— 1.10	. . . .	— .05	+ .53	—13.71	8 1 16.57	18 15 12.99	56.42	
γ Draconis, ...	W	5	8 9 29.00	+ 2.85	. . . .	+ .06	— 1.90	—12.41	8 9 17.60	18 23 13.49	55.89	
1 Aquilæ, ...	W	4	8 15 4.52	— 1.22	. . . .	+ .02	— .58	—11.49	8 14 51.25	18 28 47.95	56.70	
α Lyræ, ...	W	5	8 19 12.80	— .06	. . . .	+ .06	— .72	—10.81	8 19 1.27	18 32 57.66	56.39	+02
β Lyræ, ...	W	5	8 31 57.68	— .26	. . . .	+ .07	— .68	— 8.71	8 31 48.10	18 45 44.47	56.37	0
γ Lyræ, ...	W	5	8 40 44.70	— .27	. . . .	+ .08	— .67	— 7.27	8 40 36.57	18 54 32.88	56.31	—06
25 Camel, . . *sp.*	W	4	9 52 18.58	—10.43	. . .	— .36	+ 4.41	— 5.37	9 52 6.83	19 6 3.11	56.28	
Groombridge, 3241, .	W	5	10 16 27.80	. . . .	+ 4.25	+ .70	— 1.85	+ 8.46	10 16 39.36	20 30 34.56	55.20	
α Cygni, ...	W	5	10 23 20.58	. . . .	+ .25	+ .36	— .80	9.59	10 23 29.98	20 37 26.37	56.39	—04
ε Cygni, ...	W	5	10 27 21.80	. . . .	— .37	+ .31	— .68	10.24	10 27 31.30	20 41 27 70	56.40	—04
ν Cygni, ...	W	5	10 38 40.12	. . . .	— .00	+ .36	— .75	12.10	10 38 51.83	20 52 48.17	56.34	—10
σ² Urs. Maj., . . . *sp.*	W	5	10 45 52.36	. . . .	— 6.23	— .23	+ 1.48	13.28	10 46 0.66	8 59 56.12	55.46	
1 Pegasi, ...	W	5	11 2 28.00	. . . .	— .97	+ .28	— .60	16.01	11 2 42.73	21 16 39.12	56.40	—06

ζ Capricorni, ...	W	3	11 5 47.36	. . . .	— 2.43	+ .14	— .61	16.56	11 6 1.02	21 19 56.84	55.82	
74 Cygni, ...	E	5	11 17 58.62	. . . .	— .05	+ .22	+ .70	18.56	11 18 18.05	21 32 14.95	56.90	+20
ε Pegasi, ...	E	5	11 24 9.10	. . . .	— 1.32	+ .15	+ .54	19.57	11 24 28.04	21 38 24.76	56.72	+08
π^2 Cygni, ...	E	5	11 28 9.62	. . . .	+ .53	+ .27	+ .82	20.23	11 28 31.47	21 42 28.14	56.67	—08
79 Draconis, ...	E	3	11 37 2.97	. . . .	+ 4.63	+ .53	+ 1.85	21.69	11 37 31.67	21 51 28.59	56.92	
α Aquarii, ...	E	5	11 45 25.94	. . . .	— 1.65	+ .14	+ .53	23.07	11 45 48.03	21 59 44.65	56.62	
32 Urs. Maj., . . . *sp.*	E	5	11 55 9.90	. . . .	— 5.83	— .13	— 1.30	+24.67	11 55 27.31	10 9 23.67	10 13 56.36	

First Normal Equations.

$$56.899\delta a \quad + 42.586\delta c - 3.483x + 7.070\delta t + .991 = 0$$
$$19.828\delta a' - .576\delta c + 8.182x + 3.680\delta t + 1.282 = 0$$
$$42.586\delta a - .576\delta a' + 150.460\delta c + .062x + 3.320\delta t - 9.786 = 0$$
$$-3.483\delta a + 8.182\delta a' + .062\delta c + 60.795x + 7.380\delta t - 1.003 = 0$$
$$7.070\delta a + 3.680\delta a' + 3.320\delta c + 7.380x + 24.000\delta t - 1.100 = 0$$

Second Normal Equations.

$$12.000\delta t + 4.270x - .340 = 0$$
$$4.270\delta t + 27.613x - 1.016 = 0$$

$\delta t = +.016 \pm .021$
$x = +.034$

Assumed $\triangle T = 10h.\ 13m.\ 56.5s.$

$\delta a = -.092$ Therefore $a = -1.692$
$\delta a' = -.080$ a' -2.580
$\delta c = +.089$ c $+.639$

Therefore $\triangle T = 10h.\ 13m.\ 56^s.516. \pm .021$

We have therefore the following values of the chronometer correction and rate at Pottsville:

Date	Chronometer time.	Chronometer correction.	Probable error.	Hourly rate.
1881.	*h. m.*	*h. m. s.*		
Aug. 20,	10 40	10 2 16.068	±.024	+.0712
22,	9 35	10 10 0.329	±.027	+.046
23,	9 25	10 13 56.516	±.021	+.034

Time Determination at Washington.

The following details of work done at Washington were sent me by Prof. J. R. Eastman. For a detailed description of the instrument used, reference may be had to the vol. of Washington observations for 1865.

Clock corrections at the U. S. N. Observatory.

The observations were made with the transit circle by Assistant Astronomers Miles Rock and William C. Winlock.

Instrumental Constants.

	Sid. Hour.	*c*	*b*	*a*
		s.	*s.*	*s.*
August 20,	17.4 22.3	+0.160 0.136	—0.178	—0.167
" 22,	18.0 21.1	0.159 0.137	—0.187	—0.052
" 23,	17.2 0.2	0.162 0.105	—0.184	—0.093
September 30,	20.6 0.6	0.160 0.147	—0.167	+0.159
October 6,	19.6 1.2	0.074 0.065	—0.058	—0.599

The values of *a* were derived from all the stars on each night.

The following table contains the list of stars observed, together with reductions and the deduced clock corrections for each star.

Reductions, Clock Corrections, Etc.

Date.	Star.	Observer.	No. of threads.	Mean thread.	*Aa.*	*Bb.*	*Cc.*	Instrumental correction.	Observed place.	Ephemeris place.	Clock corrections.
1881.				*h. m. s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
Aug. 20, .	δ Ursæ Minoris, ...	W	5	18 11 9.72	+2.095	—2.029	+2.643	+2.71	12.43	36.55	—.—
	η Serpentis, ...	. .	5	15 50.41	—0.111	—0.133	+0.156	—0.09	50.32	13.03	—37.29
	1 Aquilæ, ...	. .	9	29 25.39	0.124	—0.122	+0.156	—0.09	25.30	47.98	.32
	51 Cephii, ... *sp.*	. .	8	45 7.65	2.787	+2.150	—3.156	—3.79	3.86	25.91	
	σ Sagittarii, ...	. .	9	18 48 35.29	0.169	—0.083	+0.171	—0.08	35.21	57.88	.33
	d Sagittarii, ...	. .	9	19 11 22.28	.150	.100	.160	—0.09	22.19	44.85	.34
	δ Aquilæ, ...	. .	9	20 11.37	.098	.144	.150	—0.09	11.28	33.93	.35
	κ Aquilæ, ...	.	9	31 11.07	—0.122	0.124	0.151	—0.10	10.97	33.62	.35
	λ Ursæ Minoris, ...		7	19 43 38.99	+7.006	6.250	8.144	+8.90	47.89	10.41	
	ζ Cygni, ...	. .	9	21 8 33.88	—0.031	0.202	0.163	—0.07	33.81	56.34	.47
	I Pegasi, ...	. .	9	17 16.60	.059	.178	.149	—0.09	16.51	39.11	.40
	μ Caprieroni, ...	. .	9	21 47 30.49	.138	.111	.142	—0.11	30.38	52.97	.41
	α Aquarii, ...	.	9	22 0 22.20	.107	.137	.137	—0.11	22.09	44.63	.46
	θ Aquarii, ...	. .	9	11 15.13	.124	.122	.137	—0.11	15.02	37.63	.39
	π Aquarii, ...	. .	9	22 19 53.84	—0.103	—0.140	+0.136	—0.11	53.73	16.30	37.43
Aug. 22, .	γ^2 Sagittarii, ...	W	9	17 58 53.82	—0.056	—0.077	+0.184	+0.05	53.87	14.44	—39.43
	μ Sagittarii, ...	. .	9	18 7 22.52	—0.048	0.100	0.169	+0.02	22.54	43.15	.39
	δ Ursæ Minoris, ...		8	11 14.22	+0.653	2.132	2.677	+1.20	15.42	35.78	
	η Serpentis, ...		9	15 52.39	—0.035	0.140	0.157	—0.02	52.37	13.01	.36
	1 Aquilæ, ...	.	9	29 27.34	—0.039	.128	.157	—0.01	27.33	47.96	.37
	α Lyræ, ...	. .	9	33 37.04	000	0.240	+0.199	—0.04	37.00	57.68	.32
	51 Cephei, ... *sp.*	. .	6	18 45 10.20	—0.868	+2.278	—3.156	—1.75	8.45	26.81	. . . .

Reductions, Clock Corrections, Etc.—Continued.

DATE.	STAR.	Observer.	No. of threads.	Mean thread.	*Aa.*	*Bb.*	*Cc.*	Instrumental correction.	Observed place.	Ephemeris place.	Clock corrections.
				h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
Aug. 22, .	β Lyræ,	W	9	18 46 23.82	— 0.006	—0.222	+0.183	— 0.04	23.78	44.48	39.30
	π Capricorni,	. . .	9	20 21 14.77	.046	.106	.151	0.00	14.77	35.19	.58
	ε Delphini,	. . .	9	28 15.39	.025	.168	.144	— 0.05	15.34	35.77	.57
	μ Aquarii,	. . .	9	46 58.21	— 0.039	.126	.141	— 0.02	58.19	18.55	.64
	ν Cygni,	. . .	9	20 53 27.78	+ 0.002	.246	.182	— 0.06	27.72	48.17	.55
	ζ Cygni,	. . .	9	21 8 35.96	— 0.010	—0.212	+0.158	— 0.06	35.90	56.34	.56
Aug. 23, .	α Ophiuchi,	R	9	17 30 8.20	— 0.042	—0.169	+0.164	— 0.05	8.15	27.94	—40.21
	μ Herculis,	. . .	9	42 31.37	— 0.020	—0.204	+0.179	— 0.05	31.32	51.11	.21
	γ² Sagittarii,	. . .	9	17 58 54.76	— 0.101	—0.075	+0.181	0.00	54.76	14.42	.34
	δ Ursæ Minoris,	. . .	8	18 11 14.40	+ 1.162	—2.098	+2.609	+ 1.67	16.07	35.41	
	51 Cephii, *sp.*	. . .	9	18 45 10.40	— 1.545	+2.241	—3.074	— 2.38	8.02	27.24	
	d Sagittarii,	. . .	9	19 11 25.30	— 0.083	—0.103	+0.154	— 0.03	25.27	44.82	.45
	α² Capricorni,	. . .	9	20 12 12.02	— 0.075	—0.117	+0.142	— 0.05	11.97	31.57	.40
	π Capricorni,	. . .	9	21 15.71	— 0.083	—0.104	+0.144	— 0.04	15.67	35.18	.49
	ε Delphini,	. . .	9	20 28 16.19	— 0.044	—0.165	+0.138	— 0.07	16.12	35.76	.36
	η Aquarii,	. . .	9	22 29 59.52	— 0.059	—0.142	+0.119	— 0.08	59.44	18.81	.63
	θ Piscium,	. . .	9	23 22 40.84	— 0.051	—0.155	+0.113	— 0.09	40.75	0.15	.60
	ι Piscium,	. . .	9	23 34 34.70	— 0.052	—0.153	+0.110	— 0.09	34.61	54.04	40.57
Sept. 30, .	Groombridge 3241,	R	9	20 30 56.57	— 0.284	—0.455	+0.521	— 0.22	56.35	32.65	
	μ Aquarii,	. . .	9	46 42.19	+ 0.120	—0.113	+0.161	+ 0.17	42.36	18.23	—24.13
	ν Cygni,	. . .	9	20 53 11.57	— 0.007	—0 220	+0.210	— 0.02	11.55	47.64	23.91
	σ² Ursæ Majoris, *sp.*	. . .	8	21 0 22.21	+ 0.401	+0.125	—0.418	+ 0.11	22.32	57.81	
	61 Cygni,	. . .	9	2 1.58	+ 0.002	—0.212	+0.202	— 0.01	1.57	37.61	23.96
	β Aquarii,	. . .	9	25 45.89	+ 0.113	—0.119	+0.158	+ 0.15	46.04	21.86	24.18

Oct. 6,	ξ Aquarii,	. .	9	21 31 53.30	+ 0.118	+0.115	+0.159	+ 0.16	53.46	29.29	24.17
	ε Pegasi,	. .	9	21 38 48.59	+ 0.080	—0.147	+0.159	+ 0.09	48.68	24.58	24.10
	ι Piscium,	. .	7	23 34 18.31	+ 0.089	—0.139	+0.151	+ 0.10	18.41	54.31	.10
	Groombridge 4163,	. .	7	44 34.98	— 0.325	—0.489	+0.536	— 0.28	34.70	11.40	
	ω̄ Piscium,	. .	9	23 53 40.60	+ 0.086	—0.141	+0.150	+ 0.10	40.70	16.61	.09
	α Andromedæ,	. .	9	0 2 43.08	+ 0.033	—0.187	+0.169	+ 0.02	43.10	19.09	.01
	4 Draconis, *sp.*	. .	6	6 56.72	+ 0.697	+0.376	—0.733	+ 0.34	57.06	33.06	
	12 Ceti,	. .	9	24 26.54	+ 0.110	—0.121	+0.148	+ 0.14	26.68	2.45	.23
	β Ceti,	. .	6	0 38 5.40	+ 0.142	—0.095	+0.155	+ 0.20	5.60	41.45	.15
	λ Ursæ Minoris,	R	6	19 42 11.18	+25.171	—2.042	+4.055	+27.18	38.36	16.86	
	τ Aquilæ,	. .	9	19 58 45.34	— 0.320	—0.050	+0.073	— 0.30	45.04	23.13	—21.91
	α^2 Capricorni,	. .	9	20 11 53.52	— 0.483	—0.037	+0.075	— 0.44	53.08	31.06	22.02
	ε Delphini,	. .	9	27 57.49	— 0.286	—0.052	+0.074	— 0.26	57.23	35.28	21.95
	μ Aquarii,	. .	9	46 40.58	— 0.453	—0.039	+0.073	— 0.42	40.16	18.14	22.02
	ν Cygni,	. .	9	20 53 9.38	+ 0.025	—0.076	+0.095	+ 0.04	9.42	47.51	21.91
	ι Piscium,	. .	9	23 34 16.62	— 0.335	—0.048	+0.068	— 0.32	16.30	54.31	21.99
	α Andromedæ,	. .	9	0 2 40.93	— 0.124	—0.065	+0.076	— 0.11	40.82	19.10	21.72
	γ Pegasi,	. .	9	0 7 33.23	— 0.256	—0.055	+0.069	— 0.24	32.99	11.17	21.82

The values of the clock correction and rate are then as follows:

DAY, 1881.	Epoch Sid. Hour	Clock Correction.	Hourly Rate.
	h. m.	*s. s.*	*s.*
August 20,	20 30	—37.383±0.009	—0.0321
August 22,	20 0	—39.508±0.012	—0.0833
August 23,	20 30	—40 439±0.013	—0.0602
September 30,	22 30	—24.093±0.019	—0.0211
October 6,	22 30	—21.891±0.019	+0.0360

The correction for personal equation is not included in the above corrections.

Exchange of Signals.

Two sets of arbitrary signals were sent in each direction by the operator simply breaking the circuit at intervals of about fifteen seconds. Each set consisted of from ten to thirteen signals. These were recorded at Washington on the chronograph. At Pottsville the click of the sounder was noted by me and the chronometer time recorded.

The record of the individual signals on the night of August 20th is given in full, with the resulting longitude, in order to show the character of the results. Only the means are given for the other nights. Where I did not feel satisfied with my estimation of the time by the chronometer the signal was not recorded. This will explain the blanks which occur in the following record. Number 4 of the first series and number 1 of the last have been rejected, as they seem to have been noted incorrectly,—the first by one beat of the chronometer and the second by two. From the residuals in the last column the probable error of a single comparison is found to be ±.077*s*.

Washington–Pottsville.

1881, Aug. 20.	Chronometer time.	Time from 10h. 40m.	Acceleration and rate.	Pottsville sidereal time.	Washington clock.	Washington time.	Longitude.	v.
	h. m. s.	m. s.	s.	h. m. s.	h. m. s.	h. m. s.	m. s.	
1,								
2,	10 28 53.3	11 7	—1.84	20 31 7.53	20 28 20.00	20 27 42.62	3 24.91	+ 9
3,								
4,	[10 29 23.7]	10 36	—1.75	31 38.02	[28 50.00]	28 12.62	[25.40]	[— 40]
5,	10 29 38.3	10 22	—1.71	31 52.66	29 5.00	28 27.62	25.04	— 4
6,	10 29 53.3	10 7	—1.67	32 7.70	29 20.00	28 42.62	25.08	— 8
7,	10 30 8.1	9 52	—1.63	32 22.54	29 35.00	28 57.62	24.92	+ 8
8,	10 30 23.0	9 37	—1.59	32 37.48	29 50.00	29 12.62	24.86	+ 14
9,	10 30 38.2	9 22	—1.55	32 52.72	30 5.00	29 27.62	25.10	— 10
10,	10 30 53.1	9 7	—1.51	33 7.66	30 20.00	29 42.62	25.04	— 4
11,								
12,	10 31 23.0	8 37	—1.43	20 33 37.64	20 30 50.00	20 30 12.62	25.02	— 2
	10 30 13.788				20 29 40.625		24.996	

Pottsville–Washington.

1881, Aug. 20.	Chronometer time.	Time from 10h. 40m.	Acceleration and rate.	Pottsville sidereal time.	Washington clock.	Washington time.	Longitude.	v.
	h. m. s.	*m. s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*m. s.*	
1, ...	10 35 25.1	4 35	— .75	20 37 40.42	20 34 53.00	20 34 15.62	24.80	+ 10
2, ...	10 35 41.0	4 19	— .71	37 56.36	35 9.00	34 31.62	24.74	+ 16
3, ...								
4, ...	10 36 10.3	3 50	— .63	38 25.74	35 38.32	35 0.94	24.80	+ 10
5, ...	10 36 26.5	3 34	— .58	38 41.99	35 54.10	35 16.72	25.27	— 37
6, ...								
7, ...	10 36 56.1	3 04	— .50	39 11.67	36 24.14	35 46.76	24.91	— 1
8, ...	10 37 10.6	2 49	— .46	39 26.21	36 38.72	36 1.34	24.87	+ 3
9, ...	10 37 25.6	2 34	— .42	39 41.25	36 53.76	36 16.38	24.87	+ 3
10, ...	10 37 41.1	2 19	— .38	39 56.79	37 9.26	36 31.88	24.91	— 1
11, ...	10 37 56.0	2 4	— .34	20 40 11.73	20 37 24.20	20 36 46.82	24.91	— 1
	10 36 45.811				20 36 13.833		24.898	

Washington–Pottsville.

1881, Aug. 20.	Chronometer time.	Time from 10h. 40m.	Acceleration and rate.	Pottsville sidereal time.	Washington clock.	Washington time.	Longitude.	v.
	h. m. s.	m. s.	s.	h. m. s.	h. m. s.	h. m. s.	m. s.	
1, ...								
2, ...	10 39 51.9	—0 8	— .02	20 42 7.95	20 39 20.32	20 38 42.93	25.02	— 15
3, ...	10 40 6.0	+0 6	+ .02	42 22.09	39 34.46	38 57.07	25.02	— 15
4, ...	10 40 20.7	0 21	+ .06	42 36.83	39 49.38	39 11.99	24.84	+ 3
5, ...	10 40 35.8	0 36	.10	42 51.97	40 4.44	39 27.05	24.92	— 5
6, ...	10 40 50.6	0 51	.14	43 6.81	40 19.40	39 42.01	24.80	+ 7
7, ...	10 41 5.7	1 6	.18	43 21.95	40 34.50	39 57.11	24.84	+ 3
8, ...	10 41 20.6	1 21	.22	43 36.89	40 49.46	40 12.07	24.82	+ 5
9, ...								
10, ...	10 41 50.4	1 50	.30	44 6.77	41 19.48	40 42.09	24.68	+ 19
11, ...	10 42 5.6	2 6	.34	20 44 22.01	20 41 34.50	20 40 57.11	24.90	— 3
	10 40 54.144				20 40 22.882		24.871	

Pottsville–Washington.

1881, Aug. 20.	Chronometer time.	Time from 10h. 40m.	Acceleration and rate.	Pottsville sidereal time.	Washington clock.	Washington time.	Longitude.	v.
	h. m. s.	m. s.	s.	h. m. s.	h. m. s.	h. m. s.	m. s.	
1,	[10 43 15.6]	3 16	.54	20 45 32.21	[20 42 45.78]	20 42 8.39	[23.82]	[+1.01]
2,								
3,	10 43 46.5	3 47	.62	46 3.19	43 15.72	42 38.33	24.86	+ 7
4,	10 44 1.4	4 1	.66	46 18.13	43 30.46	42 53.07	25.06	− 13
5,	10 44 16.0	4 16	.70	46 32.77	43 45.28	43 7.89	24.88	+ 5
6,	10 44 31.5	4 32	.74	46 48.31	44 0.88	43 23.49	24.82	+ 11
7,	10 44 46.6	4 47	.79	47 3.46	44 16.00	43 38.61	24.85	+ 8
8,								
9,	10 45 16.0	5 16	.88	47 32.95	44 45.36	44 7.97	24.98	− 5
10,	10 45 31.5	5 32	.92	47 48.49	45 0.94	44 23.55	24.94	− 1
11,	10 45 46.6	5 47	.96	48 3.63	45 16.24	44 38.85	24.78	+ 15
12,	10 46 1.6	6 2	1.00	20 48 18.67	20 45 30.90	20 44 53.51	25.16	− 23
	10 44 53.078				20 44 22.420		24.926	

Mean of Clock Signals from Washington to Pottsville.

Date.	Number of Signals.	Washington Clock.	Chronometer.
		h. m. s.	h. m. s.
August 20,	8	20 29 40.625	10 30 13.788
	9	20 40 22.882	10 40 54.144
August 22,	9	19 33 32.747	9 26 19.244
	9	19 47 11.029	9 39 55.256
August 23,	9	19 29 34.422	9 18 23.167
	11	19 39 19.429	9 28 6.518

Mean of Clock Signals from Pottsville to Washington.

Date.	Number of Signals.	Chronometer	Washington Clock.
		h. m. s.	h. m. s.
August 20,	9	10 36 45.811	20 36 13.833
	9	10 44 53.078	20 44 22.420
August 22,	11	9 30 55.300	19 38 9.540
	9	9 43 46.433	19 51 2.838
August 23,	9	9 21 50.778	19 33 2.613
	11.	9 32 30.300	19 43 43.911

Comparison of Longitude Signals.

	Signals from Washington to Pottsville.		Signals from Pottsville to Washington.		Difference of Longitude.		Mean.	Wave and Armature Time.
	W. Clock.	P. Chronometer.	W. Clock.	P. Chronometer.	W. to P.	P. to W.		
	20 29 40.625	10 30 13.788	20 36 13.833	10 36 45.811				
August 20,	—37.383	10 2 14.452	—37.386	10 2 15.533	*m. s.*	*m. s.*		
	20 29 3.242	20 32 28.240	20 35 36.447	20 39 1.344	3 24.998	3 24.897		
	20 40 22.882	10 40 54.144	20 44 22.420	10 44 53.078				
	—37.388	10 2 16.217	—37.390	10 2 16.876				
	20 39 45.494	20 43 10.361	20 43 45.030	20 47 9.954	3 24.867	24.924		
					3 24.932	3 24.910	3 24.921	+.011
	19 33 32.747	9 26 19.244	19 38 9.540	9 30 55.300				
	—39.472	10 9 58.896	—39.477	10 9 59.655				
	19 32 53.275	19 36 18.140	19 37 30.063	19 40 54.955	24.865	24.892		
August 22,								
	19 47 11.029	9 39 55 256	19 51 2.838	9 43 46.433				
	—39.490	10 10 1.140	—39.496	10 10 1.776				
	19 46 31.539	19 49 56.396	19 50 23.342	19 53 48.209	24.857	24.86.		
					24.861	24.880	3 24.870	—.010
	19 29 34.422	9 18 23.167	19 33 2.613	9 21 50.778				
	—40.379	10 13 55.425	—40.382	10 13 55.996				
	19 28 54.043	19 32 18.592	19 32 22.231	19 35 46.774	24.549	24.543		
August 23,								
	19 39 19.429	9 28 6.518	19 43 43.911	9 32 30.300				
	—40.388	10 13 57.030	—40.393	10 13 57.752				
	19 38 39.041	19 42 3.548	19 43 3.518	19 46 28.052	24.507	24.534		
					24.528	24.539	3 24.534	—.006
							m. s.	
						Mean	3 24.775	

The Transit Circle of the United States Naval Observatory is .066*s*. west of the center of the central dome of the observatory.

Applying this correction to the above mean we find that the Transit instrument at Pottsville was

$$3^{m.}\ 24.71^{s.}$$

east of the center of the dome of the United States Naval Observatory. This result is affected by the difference of personal equation between the observers at Washington and myself.

1881, Sept. 30. *Wilkes Barre.*

Assumed $a = -3.^{s}$
$c = -2.3$

$\triangle T$ Determined at Chronometer time 9*h.* 40*m.*

STAR.	Lamp.	No. of threads.	Mean of threads.	*Aa.*		*Bb.*	*Cc'.*		Corrected transit.	Right ascension.	N.	O–C.
			h. m. s.	*s.*		*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	
τ Draconis,	E	5	6 32 35.40	+5.43	....	—.34	—7.85	—30.79	6 32 1.85	19 17 49.85	12 45 48.00	
β Cygni,	E	5	6 40 44.54	— .78	....	—.15	—2.62	—29.45	6 40 11.54	19 25 58.28	46.74	—.10
κ Aquilæ,	E	5	6 45 20.02	—2.28	....	—.11	—2.34	—28.69	6 45 46.60	19 30 33.09	46.49	—.11
β Sagittæ,	E	5	6 50 30.60	—1.29	....	—.17	—2.44	—27.84	6 49 58.86	19 35 45.50	46.64	—.14
δ Cygni,	E	5	6 56 1.02	+ .27	....	—.28	—3.26	—26.94	6 55 30.81	19 41 17.94	47.13	+.09
Groombridge, 1374, *sp.*	E	5	7 0 44.62	—9.96	....	+.35	+8.52	—26.16	7 0 17.37	7 46 1.45	44.08	
3 Urs. Maj., *sp.*	W	5	7 15 53.50	—7.80	....	+.19	—6.33	—23.67	7 15 15.89	8 1 2.37	46.48	
ο Cygni,	W	5	7 24 27.54	+ .39	....	—.27	+3.32	—22.27	7 24 8.71	20 9 55.92	47.21	+.07
γ Cygni,	W	5	7 32 31.70	— .09	....	—.23	+2.97	—20.94	7 32 13.41	20 18 0.64	47.23	+.16
Groombridge, 3241,	W	5	7 44 52.02	+5.01	....	—.45	+7.45	—18.91	7 44 45.12	20 30 32.65	47.53	
α Delphini,	W	3	7 48 40.60	—1.35	....	—.14	+2.37	—18.29	7 48 23.19	20 34 10 28	47.09	+.21
φ Capricorni,	W	5	7 53 38.68	—3.06	....	+.06	+2.53	—17.47	7 53 20.62	20 39 7.29	46.67	
ν Cygni,	E	5	8 7 18.88	— 03	....	—.32	—3.06	—15.22	8 7 0.25	20 52 47.64	47.39	+.29
σ^2 Urs. Maj., *sp.*	E	5	8 14 26.32	—7.44	....	+.18	+6.07	—14 06	8 14 11.07	8 59 57.81	46.74	
ζ Cygni,	E	5	8 22 25.66	— .69	....	—.20	—2.67	—12.74	8 22 9.36	21 7 55.98	46.62	—.39
α Cephei,	E	5	8 30 14.66	+2.28	....	—.30	—4.95	—11.46	8 30 0.23	21 15 47.80	47.57	
ζ Capricorni,	E	4	8 34 26.54	—2.94	....	—.06	—2.50	—10.77	8 34 10.27	21 19 56.76	46.49	

β Aquarii,	E	5	8 39 49.46	—2.22	. . . .	—.06	—2.34	— 9.89	8 39 34.95	21 25 21.86	46.91	
o Cephii,	W	5	10 27 45.98	+3.45	. . . .	—.07	+5.96	+ 7.85	10 28 3.17	23 13 50.71	47.54	
λ Draconis, sp.	W	5	10 38 37.84	—8.16	. . . .	+.05	—6.67	9.63	10 38 32.69	11 24 19.36	46.67	
λ Andromedæ,	W	5	10 45 48.00	+ .36	. . . .	—.10	+3.29	10.81	10 46 2.36	23 31 49.56	47.20	—.18
i' Aquarii,	W	4	10 52 7.43	—2.76	. . . .	—.05	+2.42	11.85	10 52 18.89	23 38 6.31	47.42	
Groombridge, 4163,	E	5	11 3 13.70	+5.76	. . . .	—.22	—8.27	13.67	11 3 24.64	23 49 11.40	46.76	
ω Piscium,	E	5	11 7 19.02	—1.74	. . . .	—.07	—2.34	14.34	11 7 29.21	23 53 16.61	47.40	—.03
33 Piscium,	E	5	11 13 20.98	—2.22	. . . .	—.06	—2.34	15.34	11 13 31.70	23 59 19.19	47.49	
22 Andromedæ,	E	5	11 18 13.36	+ .33	. . . .	—.15	—3.29	16.13	11 18 26.38	0 4 13.60	47.22	—.18
44 Piscium,	E	5	11 33 20.94	—1.92	. . . .	—.10	—2.32	18.62	11 33 35.22	0 19 22.70	47.48	+.01
κ Draconis, sp.	E	5	11 42 15.60	—8.34	. . . .	+.15	+6.93	20.08	11 42 34.42	12 28 22.51	48.09	
o Cassiopeæ,	W	3	11 51 58.63	+ .51	. . . .	—.28	+3.38	21.68	11 52 23.92	0 38 11.45	47.53	+.04
δ Piscium,	W	5	11 56 24.56	—1.71	. . . .	—.12	+2.30	22.41	11 56 47.44	0 42 35.12	47.68	+.15
γ Cassiopeæ,	W	5	12 3 21.36	+1.95	. . . .	—.20	+4.59	23.55	12 3 51.25	0 49 38.67	47.42	—.08
ε Piscium,	W	5	12 10 37.76	—1.68	. . . .	—.05	+2.30	24.75	12 11 3.08	0 56 50.66	47.58	+.03
β Andromedæ,	W	5	12 16 53.74	— .39	. . . .	—.03	+2.79	+25.78	12 17 21.89	1 3 9.53	12 45 47.64	+.09

First Normal Equations.

$$34.236\,\delta a \qquad - 11.813\,\delta c - 17.337\,x + 8.850\,\delta t + 16.408 = 0 \qquad \delta a = -.501$$
$$23.407\,\delta a' - 2.949\,\delta c + 9.862\,x + 5.520\,\delta t - 3.633 = 0 \qquad \delta a' = +.054$$
$$-11.813\,\delta a - 2.949\,\delta a' + 126.559\,\delta c - 20.871\,x - .900\,\delta t - 1.730 = 0 \qquad \delta c' = -.014$$
$$-17.337\,\delta a + 9.862\,\delta a' - 20.871\,\delta c + 134.815\,x - 11.020\,\delta t - 19.656 = 0$$
$$8.850\,\delta a + 5.520\,\delta a' - 900\,\delta c - 11.020\,x + 33.000\,\delta t - 3.140 = 0$$

Second Normal Equations.

$$18.000\,\delta t - 2.450\,x - .070 = 0$$
$$-2.450\,\delta t + 88.332\,x - 8.343 = 0$$

$\delta t = +.017 \quad \pm .027$

$x = +.0949$

Therefore $a = -3.501$

$a' = -2.946$

$c = -2.314$

Assumed $\triangle T = 12\,h.\ 45m.\ 47s.25.$ Therefore $\triangle T = 12h.\ 45m.\ 47s.267 \pm 027$

1881, Oct. 6. *Wilkes Barre.*

△*T* Determined at Chronometer time 9*h*. 39*m*.

STAR.	Lamp.	No. of threads.	Mean of threads.			*Bb.*	*Cc*	Acceleration.	Corrected transit.	Right ascension.	N.	O-C.
			h. m. s.					*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	
3 Urs. Maj., . . . *sp.*	E	5	6 51 50.58	. . . . .	. . . . .	+.03	+.04	—27.46	6 51 23.19	8 1 2.71	13 9 39.52	
o' Cygni, ...	E	5	7 0 43.76	. . . . .	. . . . .	—.06	—.02	—26.00	7 0 17.68	20 9 55.76	38.08	— 2
γ Cygni, ...	E	5	7 8 47.00	. . . . .	. . . . .	—.08	—.02	—24.68	7 8 22.22	20 18 0.50	38.28	+10
Groombridge, 3241, .	E	4	7 21 17.89	. . . . .	. . . . .	—.20	—.05	—22.62	7 20 55.02	20 30 32.25	37.23	
α Delphini, ...	E	4	7 24 54.04	. . . . .	. . . . .	—.08	—.02	—22.03	7 24 31.91	20 34 10.19	38.28	— 5
ψ' Capricorni, ...	E	5	7 29 50.44	. . . . .	. . . . .	—.05	—.02	—21.22	7 29 29.15	20 39 7.19	38.04	
ν Cygni, ...	W	5	7 43 27.30	. . . . .	. . . . .	—.16	—.02	—18.98	7 43 8.14	20 52 47.51	39.37	+17
σ² Urs. Maj., . . . *sp.*	W	5	7 50 38.34	. . . . .	. . . . .	+.09	+.04	—17.80	7 50 20.67	8 59 58.16	37.49	
ζ Cygni, ...	W	5	7 58 33.24	. . . . .	. . . . .	—.11	—.02	—16.50	7 58 16.61	21 7 55.88	39.27	+10
α Cephei, ...	W	5	8 6 23.10	. . . . .	. . . . .	—.16	—.03	—15.21	8 6 7.70	21 15 47.59	39.89	
ζ Capricorni, ...	W	5	8 10 32.18	. . . . .	. . . . .	—.03	—.02	—14.53	8 10 17.60	21 19 56.68	39.08	
β Aquarii, ...	W	5	8 15 56.38	. . . . .	. . . . .	—.03	—.02	—13.65	8 15 42.68	21 25 21.79	39.11	
ε Pegasi, ...	E	5	8 28 57.64	. . . . .	. . . . .	—.09	—.02	—11.50	8 28 46.03	21 38 24.52	38.49	+ 4
π² Cygni, ...	E	5	8 33 0.54	. . . . .	. . . . .	—.15	—.02	—10.84	8 32 49.53	21 42 27.64	38.11	—11
α Aquarii, ...	E	5	8 50 14.28	. . . . .	. . . . .	—.08	—.02	— 8.01	8 50 6.17	21 59 44.51	38.34	
π Pegasi, ...	E	5	8 55 15.42	. . . . .	. . . . .	—.13	—.02	— 7.19	8 55 8.08	22 4 46.20	13 9 38.12	—28
λ Draconis, . . . *sp.*	E	3	10 14 33.57	. . . . .	. . . . .	—.00	+.05	+ 5.84	10 14 39.46	11 24 19.52	40.06	
λ Andromedæ, ...	E	5	10 22 4.12	. . . . .	. . . . .	—.04	—.02	7.07	10 22 11.13	23 31 49.54	38.41	— 2
i' Aquarii, ...	E	5	10 28 19.96	. . . . .	. . . . .	—.03	—.02	8.10	10 28 28.01	23 38 6.30	38.29	
ω̂ Piscium, ...	E	2	10 43 27.63	. . . . .	. . . . .	—.07	—.02	10.59	10 43 38.13	23 53 16.62	38.49	
33 Piscium, ...	E	2	10 49 29.45	. . . . .	. . . . .	—.07	—.02	11.58	10 49 40.94	23 59 19.20	38.26	
χ Draconis, ...	W	5	11 18 27.68	. . . . .	. . . . .	—.05	+.05	16.34	11 18 44.02	12 28 22.54	38.52	

o Cassiopeæ, ...	W	5	11 28 13.88	. . . .	. . . .	+.08	—.02	17.94	11 28 31.88	0 38 11.49	39.61	— 0
δ Piscium, ...	W	5	11 32 36.84	. . . .	. . . .	+.05	—.02	18.66	11 32 55.53	0 42 35.16	39.63	+14
γ Cassiopeæ, ...	W	5	11 39 39.16	. . . .	. . . .	+.13	—.03	19.82	11 39 59.08	0 49 38.73	39.65	—14
ε Piscium, . . .	W	5	11 46 50.20	. . . .	. . . .	+.06	—.02	21.00	11 47 11.24	0 56 50.71	39.47	— 4
β Andromedæ, . . .	W	5	11 53 7.66	. . . .	. . .	+.10	—.02	22.03	11 53 29.77	1 3 9.59	39.82	+24
37 Cassiopeæ, ...	W	5	12 8 5.00	. . . .	. . . .	+.18	—.03	24.49	12 8 29.64	1 18 9.39	39.75	— 8
38 Cassiopeæ, ...	W	3	12 12 27.59	. . . .	. . . .	+.26	—.05	+25.21	12 12 53.01	1 22 32.28	13 9 39.27	

First Normal Equations.

$$40.123a + 3.877c - 9.310x + 13.250\delta t - 10.905 = 0$$
$$3.877a + 91.524c - 28.484x - .970\delta t + 36.728 = 0$$
$$-9.310a - 28.484c + 95.942x - 7.060\delta t - 12.583 = 0$$
$$13.250a - .970c - 7.060x + 29.000\delta t - 23.910 = 0$$

$$a = + .062$$
$$c = - .368$$

Second Normal Equations.

$$15.000\delta t - .690x + 1.520 = 0$$
$$-.690\delta t + 55.011x - 5.341 = 0$$

$$x = + 0.959$$
$$\delta t = - .097 \pm .024$$

Assumed $\triangle T = 13h.\ 9m.\ 39.0s.$

Therefore $\triangle T = 13h.\ 9m.\ 38.903s. \pm .024$

Chronometer correction and rate at Wilkes Barre.

DATE.	Chronometer time.	Chronometer correction.	Probable error.	Hourly rate.
1881.	*h. m.*	*h. m. s.*		
Sept. 30, ...	9 40	12 45 47.267	±.027	+.0949
Oct. 6, ...	9 39	13 9 38.903	±.024	+.0959

Mean of clock signals from Washington to Wilkes Barre.

DATE.	Number of signals.	Washington clock.	Chronometer.
		h. m. s.	*h. m. s.*
Sept. 30, ...	11	22 12 19.478	9 30 50.055
	9	22 26 27.849	9 44 55.967
Oct. 6, ...	10	22 36 24.080	9 31 4.940
	11	22 45 49.465	9 40 28.691

Mean of clock signals from Wilkes Barre to Washington.

DATE.	Number of signals.	Chronometer.	Washington clock.
		h. m. s.	*h m. s.*
Sept. 30, ...	11	9 40 11.627	22 21 42.678
	12	9 48 54.967	22 30 27.455
Oct. 6, ...	11	9 36 51.400	22 42 11.604
	13	9 46 36.823	22 51 58.615

NOTE.—The value of the longitude of Wilkes-Barre, placed upon the monument (1 degree 10 minutes 4.6 seconds), was not corrected by the distance of the transit instrument at Washington west of the center of the observatory dome (.066 seconds of time=1.—second of arc). This difference, which for all practical purposes is immaterial, occurred from the fact that the Wilkes-Barre monument was erected before the final computation of the Washington observations had been received. [C. A. A.]

Comparison of Longitude Signals.

	Signals from Washington to Wilkes Barre.		Signals from Wilkes Barre to Washington.		Difference of Longitude.		Mean.	Wave and Armature Time.
	W. Clock.	W. B. Chronometer.	W. Clock.	W. B. Chronometer.	W. to W. B.	W. B. to W.		
	h. m. s.	*h. m. s.*	*h. m. s.*	*h. m. s.*				
Sept. 30, ...	22 12 19.478	9 30 50.055	22 21 42.678	9 40 11.627				
	— 24.087	12 45 45.747	— 24.090	12 45 47.300	*m. s.*	*m. s.*		
	22 11 55.391	22 16 35.802	22 21 18.588	22 25 58.927	4 40.411	4 40.339		
	22 26 27.849	9 44 55.967	22 30 27.455	9 48 54.967				
	— 24.092	12 45 48.085	— 24.093	12 45 48.745				
	22 26 3.757	22 30 44.052	22 30 3.362	22 34 43.712	40.295	40.350	*m. s.*	
					40.353	40.345	4 40.349	+004
Oct. 6, ...	22 36 24.080	9 31 4.940	22 42 11.604	9 36 51.400				
	— 21.887	13 9 37.590	— 21.884	13 9 38.546				
	22 36 2.193	22 40 42.530	22 41 49.720	22 46 29.946	40.337	40.226		
	22 45 49.465	9 40 28.691	22 51 58.615	9 46 36.823				
	— 21.881	13 9 39.148	— 21.878	13 9 40.166				
	22 45 27.584	22 50 7.839	22 51 36.737	22 56 16.989	40.255	40.252		
					40.296	40.239	40.268	+028
							m. s.	
					Mean.		4 40.308	

Applying to the above mean the correction due to the position of the Transit Circle at Washington west of centre of the Observatory dome, viz: .066*s*, we find that the point occupied by the Transit instrument at Wilkes Barre is

4*m.* 40.24*s.*

East of the centre of the dome of the United States Naval Observatory. The result is uncorrected for personal equation.

DECLINATIONS OF STARS USED IN DETERMINATOIN OF LATITUDE.

The list of Latitude stars observed at Wilkes Barre comprises 32 pairs. At Pottsville 25 pairs were observed.

Of the 110 different stars comprised in these 57 pairs, 51 were taken from Boss' catalogue of 500 stars published by the U. S. Northern Boundary Commission, 5 were reduced by myself in a manner entirely similar to that followed by Boss. These were included in the list prepared for determining the Latitude of the Lehigh University Observatory.* The remaining 54 stars were reduced in a similar manner expressly for this work. The purpose was to make the entire system of declinations homogeneous. The work of reduction is given somewhat in detail, and it is hoped the results may be of value beyond that of the immediate purpose for which they were derived.

The systematic corrections of Boss have been applied to the various catalogue places. Some authorities have, however, been used for which Boss gives no systematic corrections. These have generally been assigned a relatively low weight. Also the weights given in the same publication have been used with very few exceptions.

As I had access myself to a comparatively small number of star catalogues I am indebted to Prof. Boss for much of the material used. The following catalogues have been consulted. An exhaustive discussion has not, however, been attempted.

B. Fundamenta Astronomiæ pro Anno MDCCLV—Bessel's reduction of Bradley's observations.

F.L.L. Fedorenko's reduction of circumpolar stars observed by Lalande.

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* See Astronomische Nachrichten, Band 95, Nr. 2260.

Pi. Precipuarum Stellarum Inerrantium Positiones Mediæ inuente sæ culo XIX. By Joseph Piazzi.

Gr. A Catalogue of Circumpolar Stars deduced from the Observations of Stephen Groombridge, Esq., &c.

W. B. Positiones Mediæ Stellarum Fixarum in Zonis Regimontanis. Weiss' reduction of Bessel's observations.

Pond. Catalogue of 1112 stars observed at Greenwich.

Ah. Robinson's Armagh catalogue of 5345 stars.

Gh. The various Greenwich catalogues. The number immediately following refers to the epoch of the catalogue—as Gh. 40, &c.

Re. The various Radcliffe catalogues. The number following the Re. has the same significance as above, viz: Re. 45, Re. 60, &c.

Bs. The annual catalogues found in the "Annales de l'Observatoire Royal de Bruxelles."

Da. Gould's reduction of D'Agelet's Paris Observations.

Eh. Annual catalogues of the Royal Observatory in Edinburgh.

Ms. Catalogue of the principal Fixed stars from observations made at Madras by T. G. Taylor. Also Jacob's Madras Catalogue.

Rü. Rümker's Catalogue.

W^n. P. V. Observations made at Washington with the prime Vertical Transit.

W^n. M. C. Observations made with the Washington Mural Circle.

W^n. T. C. Observations made with the Washington Transit Circle.

Method of Reduction.

It was necessary to know the place of the star for 1875.0 with sufficient accuracy for computing the annual motion of the star in declination. This was accomplished as follows:

First. The place of the star for 1875.0 was taken from the best authority at hand. A few were stars which I had partially discussed on a previous occasion and for which I had values of the declination very near the finally adopted ones. Others were taken from Safford's Catalogue of 981 stars while a few were taken from the British Association Catalogue.

Secondly. The annual variation of the star was carefully computed as far as terms depending on the third power of the time and the assumed value of the declination carried back to the epoch of each catalogue in which it was found. The differences between these computed values of the declination and the catalogue values gave the data for a series of conditional equations having as unknown quantities the correction to the assumed declination and the proper motion of the star.

Thirdly. Whenever the correction to the assumed declination was large the entire operation was repeated for obtaining a second approximation to the true values. This recomputation was considered necessary in the case of twelve of the fifty-four stars. In all these cases the corrections obtained by this last approximation were quite small and for practical purposes might have been neglected.

Formulæ of Reduction.

Let δ_0 = The star's declination for 1875.0

δ = The star's declination for 1875.$-t$; t being expressed in years.

Then Maclaurin's formula gives us

$$\delta = \delta_0 - \frac{d\delta}{dt}.\, t + \frac{d^2\delta}{dt^2}\,\frac{t^2}{1.2} - \frac{d^3\delta}{dt^3}\cdot\frac{t^3}{1.2.3}$$

The formulæ for these differential co-efficients using Peters' constants for 1875.0, are as follows:

$$^{*}\frac{d\delta}{dt} = [1.302\ 206]\cos\alpha + \mu'$$

$$\frac{d^2\delta}{dt^2} = -[4.63380]\left(\frac{d\delta}{dt} - \mu'\right) - [7.16387]\left(\frac{d\alpha}{dt} + \mu'\right)\sin\alpha - [6.737]\,\mu'^2\sin 2\delta$$

* For the derivation of these formulæ see Mr. G. W. Hill's paper "On the derivation and reduction of places of the Fixed Stars," published in the volume of Star Tables of the American Ephemeris.

$$\frac{d^3\delta}{dt^3}=[2.09871]\left(\frac{da}{dt}+\frac{\mu}{2}\right)\sin a-[7.16387]\Big)\frac{d^2a}{dt^2}+\frac{d\mu}{dt}\sin a$$

$$-[3.02554]\left(\frac{da}{dt}+\mu\right)\frac{da}{dt}\cos a$$

The formulæ for $\frac{da}{dt}$ $\frac{d^2a}{dt^2}$ & $\frac{d\mu}{dt}$ in the above formulæ are as follows:

$$\frac{da}{dt}=3.07225+[0.126115]\sin a\tan\delta+\mu$$

$$\frac{d^2a}{dt^2}=0.0000322s-[4.63380]\left(\frac{da}{dt}-\mu\right)+[5.98778]\left(\frac{da}{dt}+\mu\right)$$

$$\cos a\tan\delta+[4.81169]\left(\frac{d\delta}{dt}+\mu'\right)\sin a\sec^2\delta+[4.987]\mu\mu'\tan\delta$$

$$\frac{d\mu}{dt}=[5.98778]\mu\cos a\tan\delta+[4.81169]\mu'\sin a\sec^2\delta+$$

$$[4.987]\mu\mu'\tan\delta$$

In the above

μ=proper motion in right ascension given in seconds of time.
μ'= " declination " arc.

The algebraic signs of the differential co-efficients are general. In applying the formulæ the proper signs must be applied to t, t^2 & t^3.

The numerical quantities enclosed in brackets are logarithms. In all cases except in the formulæ for $\frac{da}{dt}$ and $\frac{d\delta}{dt}$ the logarithms have been increased by 10.

The formation of the equations of condition is as follows:

Let δ=The star's declination as given by catalogue,
$\delta_{,}$=Computed value at epoch of catalogue,
$\triangle\delta$=Correction to the assumed δ,
$\triangle\mu'$= " " " proper motion,
$1875-t$=Epoch of catalogue,
p=The weight assigned to any catalogue place,

Then each catalogue place gives an equation for determining $\triangle\delta$ & $\triangle\mu'$ of the form.

$$\sqrt{p}\,[\triangle\delta-t\triangle\mu'=\delta-\delta_{,}]$$

Using the common notation the normal equations will then be as follows:

$$[p] \triangle\delta - [pt] \triangle\mu' - [pu] = 0$$
$$-[pt] \triangle\delta + [ptt] \triangle\mu' + [ptu] = 0$$

Eliminating first $\triangle\delta$ we have $\triangle\mu'$ with its weight, then eliminating $\triangle\mu'$ we have $\triangle\delta$ with its weight.

Let $p_{\mu'}$ = Weight of $\triangle\mu'$,

p_δ = " $\triangle\delta$, Then we shall have

$$p_{\mu'} = [ptt] - \frac{[pt]}{[p]}[pt]$$
$$p_\delta = [p] - \frac{[pt]}{[ptt]}[pt]$$

For checking the computation the residuals were formed and the sum of the squares of the residuals multiplied by the respective weights of the equations. Or according to the common notation the quantity $[pvv]$. Then according to well known principles

$$[pvv] = [puu.2]$$

Then let ε = The mean error of a catalogue place of weight unity.

$\varepsilon\mu'$ = The mean error of computed value of proper motion.

$\varepsilon\delta$ = The mean error of computed value of declination.

m = The number of equations of condition.

$$\text{Then } \varepsilon = \sqrt{\frac{[pvv]}{m-2}} \; . \; \varepsilon_\delta = \frac{\varepsilon}{\sqrt{p_{\mu'}}} . \; \varepsilon_{\mu'} = \frac{\varepsilon}{\sqrt{p_\delta}}$$

The computation of $\frac{d\delta}{dt}$ was checked by duplicate computation in certain cases and by comparison with the annual motion from other catalogues brought up to 1875 by applying the secular variation.

$\frac{d^2\delta}{dt^2}$ was checked in a similar manner.

For checking $\frac{d^3\delta}{dt^3}$ an independent computation of its value was made from the tables given for this purpose by Argelander. "*Untersuchungen über die Eigenbewegungen von 250 Sternen.*"

The reduction of the assumed declination to the epoch of the various catalogues was checked by differences when the intervals were favorable, by duplicate computation in other cases, and whenever the discrepancies were considerable the computation was carefully reviewed. The systematic corrections were applied directly to the catalogue places, also the corrections due to the value of the proper motion assumed. When the mean epoch of observation is given that date has generally been used in forming the equations of condition instead of the epoch to which the catalogue is reduced.

In the following pages are given some of the details of the reduction with the final results. It will probably be understood without further explanation.

6123.

$\delta = 2° 31' 49''.28.$
$\mu' = 1.'' 1351.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B., ...	5	.2	120	+ .76	+ .57
Pi., ...	18	.1	75	— 2.89	— 2.97
Ah, ...	5	.2	26	+ 1.31	+ 1.34
Gh. 45, . .	5	1.0	30	— .20	— .18
Gh. 60, . .	5	1.5	15	+ .64	+ .70
Gh. 72, . .	5	.3	1	— .10	— .01
Bs., . . .	7	2.0	12	— .50	— .44
Bs., .	5	.5	0	— 1.37	— 1.28
Wn. M. C.,	6	.8	4	+ .66	+ .74

Normal Equations.

$$6.60 \; \triangle\delta - 1.167 \; \triangle\mu' + .302 = 0$$
$$-1.167 \; \triangle\delta + .512 \; \triangle\mu' + .018 = 0$$

$$\triangle\delta = -.091 \pm .245$$
$$100 \; \triangle\mu' = -.235 \pm .878$$

Final Values.

$$\delta = 2° 31' 49''.19 \pm .24$$
$$\mu' = -1.1374'' \pm 88$$

6468.

$\delta = 36° 48' 36''.00.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B., . .	3	.1	120	+ 3.72	+ .58
W. B., .	.	.05	50	+ 2.40	+ .56
Ah., . .	5	.2	32	+ 1.01	— .49
Ms., . .	4	.3	25	+ .51	— .86
Bs., . .	2	.8	9	+ 1.11	+ .04
Gh. 72, .	3	.4	3	+ 1.57	+ .61

Normal Equations.

$$1.85 \; \triangle\delta - .368 \; \triangle\mu' - 2.363 = 0$$
$$-.368 \; \triangle\delta + .201 \; \triangle\mu' + .708 = 0$$

$$\triangle\delta = + .907 \pm .211$$
$$100 \; \triangle\mu' = -1.860 \pm .639$$

Final Values.

$$\delta = 33° 48' 36''.91 \pm 21$$
$$\mu' = -.0186 \pm 64$$

6566.

$\delta = 50° 9' 45''.80.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
F. L. L.,	1	.05	85	+ 5.29	+ 3.25
Gr., .	6	.3	65	— .42	— 2.00
Gh. 40, .	6	.8	39	+ 1.25	+ .26
Gh. 45, .	5	1.0	30	+ 1.20	+ .41
Re. 45, .	4	.4	31	+ 1.06	+ .25
Ms., . .	5	.3	25	+ 1.61	+ .94
Bs., . .	2	.8	9	— .54	— .85
Wn. T. C.,	7	.3	5	+ .59	+ .37

Normal Equations.

$$3.95 \; \triangle\delta - 1.136 \; \triangle\mu' - 2.991 = 0$$
$$-1.136 \; \triangle\delta + .439 \; \triangle\mu' + 1.115 = 0$$

$$\triangle\delta = + .105 \pm .458$$
$$100 \; \triangle\mu = -2.277 \pm 1.375$$

Final Values.

$$\delta = 50° 9' 45''.90 \pm 46$$
$$\mu' = -.0228 \pm 137$$

6583.

$\delta = 56^\circ\ 38\ \ 47''.90.$

Authority.	No. of obs.	Wt.	1875—t.	O-C.	v.
B, ...	5	.2	120	—4.64	— .76
Pi, ...	9	.1	75	—2.44	— .27
Gr, ...	9	.3	65	—1.92	— .13
Ah, ...	3	.2	22	— .13	+ .03
Gh. 40, . .	18	1.5	35	— .24	+ .42
Gh. 45, . .	2	.4	32	—1.16	— .62
Re. 45, . .	5	.4	39	— .26	+ .55
Gh. 60, . .	4	1.0	15	+ .28	+ .18
Gh. 72, . .	6	1.0	5	— .08	— .56

Normal Equations.

$$5.10\ \triangle\delta - 1.563\triangle\mu' + 2.502 = 0$$
$$-1.563\triangle\delta + .792\triangle\mu' - 1.954 = 0$$

$$\triangle\delta = + .671 \pm 179$$
$$100\triangle\mu' = + 3.793 \pm 453$$

Final Values.

$\delta = 56^\circ\ 38'\ 48''.57 \pm 18$

$\mu' = +''.0379 \pm 45$

6637.

$\delta = 26^\circ\ 1'\ 28''.30.$

Authority.	No. of obs.	Wt.	1875—t.	O-C.	v.
B, . . .	3	.1	120	+1.04	+1.75
Pi, . .	9	.1	75	—3.01	—1.57
W. B., .	.	.05	50	—7.69	—5.84
Ah, .	2	.2	20	—1.62	+ .72
Gh. 64, .	3	1.0	10	—2.22	+ .28
Gh. 72, .	26	2.0	3	—2.69	— .08

Normal Equations.

$$3.45\ \triangle\delta - .420\triangle\mu' + 8.505 = 0$$
$$- .420\triangle\delta + .232\triangle\mu' - .741 = 0$$

$$\triangle\delta = -2.662 \pm 318$$
$$100\triangle\mu' = -1.624 \pm 1.227$$

Final Values.

$\delta = 26^\circ\ 1'\ 25''.64 \pm .32$

$\mu' = -''.0162 \pm 123$

6851.

$\delta = 34^\circ\ 45'\ 3''.60.$

Authority.	No. of obs.	Wt.	1875—t.	O-C.	v.
B, . .	4	.2	120	+4.30	— .07
Pi, . .	11	.1	75	+3.44	+1.04
W. B.,. .	. .	.05	50	— .32	—1.62
Ah, .	5	.2	32	+ .59	+ .08
Gh. 60, .	4	1.0	15	— .32	— .09
Gh. 72, .	2	.5	3	+ .40	+1.16
Bs.,	4	1.5	5	—1.15	— .48
Wn.T.C.,	3	.4	0	— .40	+ .49

Normal Equations.

$$3.95\ \triangle\delta - .644\triangle\mu' + .699 = 0$$
$$- .644\triangle\delta + .403\triangle\mu' + 1.192 = 0$$

$$\triangle\delta = - .891 \pm 186$$
$$100\triangle\mu' = -4.382 \pm 583$$

Final Values.

$\delta = 34^\circ\ 45'\ 7''.71 \pm 19$

$\mu' = -''.0438 \pm 58$

6933.

$\delta = 20^{\circ}\ 32\ 41''.47.$
$\mu' = +.0920.$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
B,	3	.1	120	—.35	—.27
Pi,	14	.1	75	—.32	—.18
W. B.,		.05	50	—3.29	—3.11
Ah,	7	.3	32	+.90	+1.10
Gh64,	2	.7	19	—.04	+.18
Wn. T.C.,	3	.4	2	—.32	—.08
Bs,	1	.5	3	—.70	—.46

Normal Equations.

$$2.15\ \triangle\delta - .472\triangle\mu + .467 = 0$$
$$-.472\triangle\delta + .269\triangle\mu - .080 = 0$$

$$\triangle\delta = -.247 \pm .258$$
$$100\triangle\mu' = -.136 \pm .729$$

Final Values.

$$\delta = 20^{\circ}\ 32'\ 41''.22 \pm 26$$
$$\mu' = +\ ''.0906 \pm 73$$

7246.

$\delta = 26^{\circ}\ 37'\ 47''.87.$
$\mu' = -.0768.$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
B,	3	.1	120	+.54	+.10
Pi,	12	.1	75	+.09	—.19
W. B.,		.0	50	—4.38	[—5.57]
Ah,	5	.2	25	+1.56	+1.46
Gh 50,	9	1.0	22	+.21	—.30
Bs,	3	1.0	6	+.05	—.08
Gh 72,	20	2.0	1	—.07	+.05

Normal Equations.

$$4.40\ \triangle\delta - .545\triangle\mu' - .255 = 0$$
$$-.545\triangle\delta + .265\triangle\mu' + .102 = 0$$

$$\triangle\delta = +.014$$
$$100\triangle\mu' = -.354$$

Final Values.

$$\delta = 26^{\circ}\ 37'\ 47''.88$$
$$\mu' = -\ ''.0803$$

7273.

$\delta = 44^{\circ}\ 26'\ 41''.10$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
Gr,	6	.3	65	+.33	—.04
W. B.,		.05	50	—2.05	—2.24
Re 45,	6	.5	33	—.36	—.34
Ms,	4	.3	25	+1.71	+1.83
Wn TC.,	3	1.0	7	—.59	—.25

Normal Equations.

$$2.15\ \triangle\delta - .530\triangle\mu' + .260 = 0$$
$$-.530\triangle\delta + .217\triangle\mu' + .041 = 0$$

$$\triangle\delta = -.421$$
$$100\triangle\mu' = -1.221$$

Final Values.

$$\delta = 44^{\circ}\ 26'\ 40''.68$$
$$\mu' = -\ ''.0122$$

7361.

$\delta = 22^\circ\ 34'\ 18''.20.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
W. B., . .		.05	50	— .61	— .48
Ah., . .	5	.2	24	— 2.16	+ .31
Gh. 64, . .	3	1.0	10	— 3.79	— .06

Normal Equations.

$$1.25\ \triangle\delta - .173\ \triangle\mu' + 4.253 = 0$$
$$-.173\ \triangle\delta + .034\ \triangle\mu' - .499 = 0$$

$$\triangle\delta = -4.632$$
$$100\ \triangle\mu' = -9.000$$

Final Values.

$$\delta = 22^\circ\ 34'\ 13''.57$$

$$\mu' = -\ ''.0900$$

7402.

$\delta = 43^\circ\ 25'\ 14''.00.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Gr, . . .	6	.3	65	+ 1.96	+ .23
Ah, . .	5	.2	32	+ .84	+ .07
Re, . .	3	.3	30	+ .12	— .57
Ms.,	4	.3	25	+ .27	— .27
Wn.M.C.	2	.1	21	+ 1.08	+ .66
Gh. 64, .	3	1.0	9	+ .12	+ .05
Wn.M.C.	1	.1	0	+ .27	+ .47

Normal Equations.

$$2.30\ \triangle\delta - .535\ \triangle\mu' - 1.128 = 0$$
$$-.535\ \triangle\delta + .205\ \triangle\mu' + .501 = 0$$

$$\triangle\delta = -.198 \pm .448$$
$$100\ \triangle\mu' = -2.965 \pm 1.501$$

Final Values.

$$\delta = 43^\circ\ 25'\ 13''.80 \pm 45$$

$$\mu' = -\ ''.0296 \pm 150$$

7462.

$\delta = 36^\circ\ 34'\ 27''.10.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Da., . .	2	.05	90	— 1.15	— 1.82
Pi, . .	9	.1	75	+ 1.42	+ .84
W. B., .		.05	50	— .01	— .42
Ah., . .	5	.2	35	— .14	— .46
Wn.P.V.,	2	.4	27	+ .50	+ .24
Wn.M.C.	4	.4	16	+ .76	+ .57
Bs., . .	2	.8	11	+ .25	+ .09
Gh. 72, .	8	1.5	4	— .07	— .18

Normal Equations.

$$3.50\ \triangle\delta - .535\ \triangle\mu' - .655 = 0$$
$$-.535\ \triangle\delta + .185\ \triangle\mu' + .167 = 0$$

$$\triangle\delta = + .088 \pm 137$$
$$100\ \triangle\mu' = -.651 \pm 595$$

Final Values.

$$\delta = 36^\circ\ 34'\ 27''.19 \pm 14$$

$$\mu' = -\ ''.0065 \pm 60$$

7544.

$\delta = 42° \; 42' \; 24''.60.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B	5	.2	120	+ .15	+ .24
Pi, ...	8	.1	75	+ .52	+ .44
Gr, ...	6	.3	65	+ .12	+ .01
W. B., . .	. .	.05	50	—1.79	—1.95
Ah, ...	6	.3	36	—2.59	—2.80
Re, ...	4	.4	31	+ .76	+ .54
Gh 60, . .	10	2.0	19	+ .87	+ .61
Gh 64, . .	2	.7	11	— .70	— .99
Gh 72, .	5	1.0	11	+ .65	+ .36
Wn. T. C.,	3	.4	— 1	— .29	— .62

Normal Equations.

$$5.45 \, \triangle\delta - 1.330 \, \triangle\mu' - 1.339 = 0$$
$$-1.330 \, \triangle\delta + .652 \, \triangle\mu' + .219 = 0$$

$$\triangle\delta = +.326 \pm 299$$
$$100 \, \triangle\mu' = +.330 \pm 865$$

Final Values.

$$\delta = 42° \; 42' \; 24''.93 \pm 30$$

$$\mu' = +''.0033 \pm 86$$

7585.

$\delta = 22° \; 22' \; 23''.08.$
$\mu = -.0373.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	2	.1	120	— .86	— .84
Pi, . .	6	.1	75	— .05	— .03
W. B., .	. .	.05	50	+ .74	+ .77
Ah, . .	5	.2	28	+2.25	+2.28
Bs, . .	2	.8	4	+ .15	+ .19
Gh 64, .	3	1.0	9	— .59	— .55
Wn.T.C.,	4	.5	1	— .04	— .00

Normal Equations.

$$2.75 \, \triangle\delta - .403 \, \triangle\mu' + .094 = 0$$
$$- .403 \, \triangle\delta + .238 \, \triangle\mu' - .011 = 0$$

$$\triangle\delta = -.036 \pm 251$$
$$100 \, \triangle\mu' = -.016 \pm 855$$

Final Values.

$$\delta = 22° \; 22' \; 23''.04 \pm 25$$

$$\mu' = -''.0375 \pm 85$$

7668.

$\delta = 57° \; 3' \; 37''.40.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	4	.2	120	+1.21	— .16
Pi, . . .	6	.1	75	+ .41	— .48
Ah, . .	5	.2	34	+2.15	+1.69
Re 45, .	4	.4	27	— .17	— .55
Re 60, .	5	.4	17	+ .77	+ .49
Gh 64, .	4	1.0	8	+ .48	+ .30
Bs, . . .	2	.8	7	— .49	— .66

Normal Equations.

$$3.10 \, \triangle\delta - .695 \, \triangle\mu' - 1.041 = 0$$
$$- .695 \, \triangle\delta + .418 \, \triangle\mu' + .511 = 0$$

$$\triangle\delta = + .098 \pm 241$$
$$100 \, \triangle\mu' = -1.061 \pm 655$$

Final Values.

$$\delta = 57° \; 3' \; 37''.50 \pm 24$$

$$\mu' = -''.0106 \pm 65$$

7824.

$\delta = 50° 37' 14''.50$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Pi,	10	.1	.75	— .32	+1.07
Gr,	6	.3	.65	—1.54	— .46
Re 45,	3	.3	.30	+ .14	+ .11

Normal Equations.

$.70\ \triangle\delta - .360\mu' + .452 = 0$

$-.360\triangle\delta + .210\mu' - .311 = 0$

$\triangle\delta = + .977$

$100\mu' = + 3.160$

Final Values.

$\delta = 50° 37' 15''.48$

$\mu' = + .0316$

7931.

$\delta = 38° 48' 39''.50$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Gr,	7	.3	65	+1.48	+ .43
W. B.,		.05	50	—2.03	—2.71
Ah,	5	.2	28	—1.25	—1.40
Re 45,	4	.4	29	— .03	— .20
Ms,	4	.3	25	+1.24	+1.17
Wn TC,	4	.5	—2	— .55	+ .04

Normal Equations.

$1.75\ \triangle\delta - .457\mu' - .177 = 0$

$-.457\triangle\delta + .208\mu' + .264 = 0$

$\triangle\delta = - .540 \pm .430$

$100\mu' = - 2.450 \pm 1,245$

Final Values.

$\delta = 38° 48' 38''.96 \pm 43$

$\mu' = - .0245 \pm 124$

7932.

$\delta = 41° 9' 49''.40$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	3	.1	120	— .61	— .44
Pi,	7	.1	75	+1.33	+1.45
Gr,	6	.3	65	— .44	— .30
Ms,	4	.2	40	—1.52	—1.43
Rü,	1	.1	28	— .06	+ .02
Ah,	5	.2	33	— .42	— .34
Eh 43,	3	.6	31	— .79	— .71
Re 45,	5	.4	28	+1.81	+1.89
Wn M C,	3	.1	21	— .49	— .42
Gh 65,	4	1.0	9	— .00	+ .06

Normal Equations.

$3.10\ \triangle\delta - .973\mu' + .253 = 0$

$-.973\triangle\delta + .500\mu' - .099 = 0$

$\triangle\delta = - .050 \pm 335$

$100\mu' = + .100 \pm 834$

Final Values.

$\delta = 41° 9' 49''.35 \pm 33$

$\mu' = + .0010 \pm 83$

7972.

$\delta = 42^\circ\ 38'\ 54''.30.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B.,	3	.1	120	+ .77	+ 1.05
Pi.,	7	.1	75	— 2.10	— 1.76
Gr.,	5	.2	65	— .43	— .08
W. B.,	.	.05	50	— .61	— .24
Ah.,	5	.2	34	— .97	— .58
Re. 60,	5	.4	18	+ .74	+ 1.15
Gh. 60,	2	.7	19	— .25	+ .16
Gh. 64,	3	1.0	11	— .84	— .42
Gh. 72,	5	1.0	0	— .46	— .02
Bs.,	4	1.5	4	— .38	+ .05

Normal Equations.

$$5.25\ \triangle\delta - .793\ \mu' + 2.193 = 0$$
$$-.793\ \triangle\delta + .372\ \mu' - .299 = 0$$

$$\triangle\delta = -.437 \pm .138$$
$$100\mu' = -.127 \pm .518$$

Final Values.

$$\delta = 42^\circ\ 38'\ 53''.86 \pm 14$$
$$\mu' = -.0013 \pm 52$$

7984.

$\delta = 39^\circ\ 42'\ 38''.40.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Da.,	1	.05	92	— 1.74	— .23
Gr.,	4	.2	63	— 2.50	— 1.38
Ah.,	4	.2	27	+ 1.44	+ 2.07
Re. 45,	3	.3	28	+ .90	+ 1.55
Ms.,	3	.1	25	— .50	+ .11
Bs.,	2	.8	8	— 1.37	— .99
Gh. 72,	9	.3	1	+ .35	+ .63

Normal Equations.

$$1.95\ \triangle\delta - .402\ \mu' + 1.070 = 0$$
$$-.402\ \triangle\delta + .171\ \mu' - .340 = 0$$

$$\triangle\delta = -.270 \pm .503$$
$$100\ \mu' = +1.353 \pm 1.702$$

Final Values.

$$\delta = 39^\circ\ 42'\ 38''.13 \pm 50$$
$$\mu' = +.0135 \pm 170$$

8079.

$\delta = 26^\circ\ 10'\ 20''.25.$
$\mu' = -.1376.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B.,	4	.2	120	— .14	— .35
Pi.,	7	.1	75	+ 1.56	+ 1.34
W. B.,	.	.0	50	— 3.02	[— 3.24]
Ah.,	5	.2	22	+ .96	+ .74
Re. 60,	9	.5	18	+ .15	— .07
Bs.,	6	1.0	10	— .68	— .90
Gh. 64,	3	1.0	9	+ .75	+ .52
Gh. 72,	12	1.5	1	+ .35	+ .12
Wn.T.C.,	2	.3	1	+ .29	+ .06

Normal Equations.

$$4.80\ \triangle\delta - .657\ \triangle\mu' - 1.077 = 0$$
$$-.657\ \triangle\delta + .388\ \triangle\mu' + .144 = 0$$

$$\triangle\delta = +.226 \pm .169$$
$$100\ \triangle\mu' = +.010 \pm .593$$

Final Values.

$$\delta = 26^\circ\ 10'\ 20''.48 \pm 17$$
$$\mu' = -.1375 \pm 59$$

8118.

$\delta = 41° 5' 28''.10$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	3	.1	120	+2.02	+.02
Pi,	7	.1	75	+ .73	—.56
Gr,	6	.3	65	+1.76	+.62
W. B.,		.05	50	+1.94	+1.04
Ah,	5	.2	35	+ .18	—.49
Re 45,	4	.4	30	+ .05	—.54
Gh 64,	3	1.0	8	— .02	—.26
Gh 72,	3	.7	3	+ .73	+.56

Normal Equations.

$$2.85\ \triangle\delta - .706\mu' - 1.447 = 0$$
$$- .706\triangle\delta + .406\mu' + .720 = 0$$

$$\triangle\delta = + .120 \pm 173$$
$$100\mu' = - 1.565 \pm 457$$

Final Values.

$$\delta = 41° 5' 28''.22 \pm 17$$
$$\mu' = - .0156 \pm 46$$

8138.

$\delta = 61° 31' 47''.20$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	1	.05	120	—4.27	+1.08
F. L. L.,	1	.05	85	—6 38	—1.88
Ah,	5	.2	28	—2.85	+ .27
Re 45,	2	.3	26	—3.15	— .08

Normal Equations.

$$.60\ \triangle\delta - .236\mu' + 2.048 = 0$$
$$-.236\triangle\delta + .144\mu' - .932 = 0$$

$$\triangle\delta = - 2.445$$
$$100\mu' = + 2.423$$

Final Values.

$$\delta = 61° 31' 44''.76$$
$$\mu' = + .0242$$

8147.

$\delta = 19° 52' 29''.10$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
LL,	1	.05	75	+1.10	+2.46
W. B.,		.05	50	—6.89	—5.11
Ah,	4	.2	30	—1.11	+1.01
Ms,	3	.1	25	—2.73	— .53
Re 60,	3	.3	15	—2.92	— .56
Gh 64,	3	1.0	8	—2.61	— .12
Bs,	3	1.0	8	—2.21	+ .27

Normal Equations.

$$2.70\ \triangle\delta - .353\mu' + 6.480 = 0$$
$$- .353\triangle\delta + .084\mu' - .783 = 0$$

$$\triangle\delta = - 2.620 \pm 385$$
$$100\mu' = - 1.684 \pm 2.179$$

Final Values.

$$\delta = 19° 52' 26''.48 \pm 38$$
$$\mu' = - .0168 \pm 218$$

8293.

$\delta = 8^\circ\ 37'\ 15''.60.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, ...	3	.1	120	+6.92	—23
Pi, ...	12	.1	75	+4.03	+20
Ah, . . .	5	.2	25	+ .38	+23
Gh 64, . .	3	1.0	10	—1.00	—04

Normal Equations.

$$1.40\ \triangle\delta - .345\mu' - .171 = 0$$
$$-\ .345\triangle\delta + .222\mu' + 1.051 = 0$$

$$\triangle\delta = -1.692$$
$$100\mu' = -7.365$$

Final Values.

$$\delta = 8^\circ\ 37'\ 13''.91$$

$$\mu' = -.0736$$

8330.

$\delta = 55^\circ\ 3'\ 33''.30.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . .	4	.2	120	— .38	— .45
Pi, . . .	12	.1	75	+ .24	+ .09
Gr, . . .	6	.3	65	— .10	— .27
Ah, . .	5	3	33	+ .98	+ .75
Gh 40, .	1	.2	36	+2.68	+2.46
Gh 45, .	7	1.0	30	— .05	— .28
Re 45, .	4	.4	34	+ .09	— .13
Gh 50, .	2	.3	26	+ .74	+ .50
Wn.M.C.	2	.4	9	— .65	— .92

Normal Equations.

$$3.20\ \triangle\delta - 1.231\mu' - 696 = 0$$
$$-1.231\triangle\delta + .689\mu' + 229 = 0$$

$$\triangle\delta = +.287 \pm 351$$
$$100\mu' = +.180 \pm 757$$

Final Values.

$$\delta = 55^\circ\ 3\ \ 33''.59 \pm 35$$

$$\mu' = +.0018 \pm 76$$

8350.

$\delta = 26^\circ\ 25'\ 13''.36.$
$\mu' - .9796.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	4	.1	120	+2.14	+3.02
Pi, . .	7	.1	75	—5.59	—5.03
W. B , .	.	.05	50	—2.03	—1.65
Ah, .	7	.3	29	+1.32	+1.55
Re 60, .	3	.3	15	—1.86	—1.73
Bs, . .	4	1.5	11	— .30	— .19
Gh 64, .	3	1.0	9	+ .31	+ .40
Gh 72, .	7	1.0	1	+ .30	+ .33
Wn.M.C.	2	.2	7	— .58	— .50

Normal Equations.

$$4.55\ \triangle\delta - .631\triangle\mu' + .567 = 0$$
$$-\ .631\triangle\delta + .272\triangle\mu' - .209 = 0$$

$$\triangle\delta = -.027 \pm\ .339$$
$$100\triangle\mu' = +.707 \pm 1.384$$

Final Values.

$$\delta = 26^\circ\ 25'\ 13''.33 \pm 34$$

$$\mu' = -.9725 \pm 138$$

16.

$\delta = 45^\circ\ 22'\ 35''.30.$

AUTHORITY.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	5	.2	120	+ .15	— .65
Pi,	8	.1	75	+ .32	— .30
Da.,	3	.05	91	— .49	— 1.17
	3	.05	75	+ 1.51	+ .89
Gr.,	6	.3	66	+ .27	— .32
W. B.,	1	.05	47	— 1.15	— 1.66
Pond.,	12	.8	45	+ 1.30	+ .80
Ms.,	5	.2	40	+ 1.17	+ .68
Ah.,	11	.3	35	+ .27	— .20
Eh.,	3	.2	36	+ 1.12	+ .65
OA.,	1	.1	32	+ .58	+ .12
Re. 45,	3	.3	30	+ .86	+ .41
Gh. 60,	3	1.0	15	— .20	— .59
Re. 61,	1	.2	14	— .25	— .63
D. M.,	. . .	.5	0	+ .51	+ .18

Normal Equations.

$$4.35\ \triangle\delta - 1.538\ \mu' - 2.036 = 0$$
$$-1.538\ \triangle\delta + .875\ \mu' + .849 = 0$$

$$\triangle\delta = +.330 \pm 180$$
$$100\ \mu' = -.390 \pm 402$$

Final Values.

$$\delta = 45^\circ\ 22'\ 35''.63 \pm 18$$

$$\mu' = -.0039 \pm .40$$

8373.

$\delta = 63° 30' 0''.8.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	3	.1	120	— .67	— 1.04
Pi,	8	.1	75	— 1.26	— 1.64
Gr.,	6	.3	65	+ .92	+ .53
Ah.,	5	.2	24	— .13	— .51
Gh. 40,	9	1.0	35	+ .79	+ .39
Re. 45,	4	.4	29	+ .73	+ .33
Gh. 72,	10	1.5	1	+ .21	— .20

Normal Equations.

$$3.60 \triangle\delta - .919\,\mu' - 1.454 = 0$$
$$.919 \triangle\delta + .495\,\mu' + .362 = 0$$

$$\triangle\delta = + .413 \pm 190$$
$$100\,\mu' = + .035 \pm 512$$

Final Values.

$$\delta = 63° 30' 1''.21 \pm 19$$
$$\mu' = .0003 \pm 51$$

8.

$\delta = 17° 31' 1''.24.$
$\mu' = - .0290.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	3	.1	120	+ 1.04	+ 1.05
Pi,	9	.1	75	— 1.32	— 1.33
Ah.,	2	.2	24	— .84	— .87
Re. 60,	3	.3	16	+ .40	+ .37
Gh. 64,	5	1.5	8	— .10	— .14
Gh. 72,	4	.8	3	+ .40	+ .36
Bs.,	3	1.0	9	— .06	+ .09

Normal Equations.

$$4.00 \triangle\delta - .525 \triangle\mu' - .034 = 0$$
$$- .525 \triangle\delta + .239 \triangle\mu' - .002 = 0$$

$$\triangle\delta = + .013 \pm 139$$
$$100 \triangle\mu' = + .038 \pm 569$$

Final Values.

$$\delta = 17° 31' 1''.25 \pm 14$$
$$\mu' = - .0286 \pm 57$$

52.

$\delta = 37° 59' 15''.70.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	5	.2	120	+ 2.94	+ .83
Pi,	6	.1	75	+ .29	— .65
Ah.,	5	.2	35	+ .60	+ .69
Re. 45,	3	.3	20	— .99	— .51
Gh. 50,	30	2.0	26	— .75	— .42
Re. 60,	1	.2	15	+ .11	+ .72
Bs.,	3	1.0	7	— .71	+ .11
Wn. P.V.,	1	.2	27	— .16	+ .14
Gh. 72,	6	1.0	3	— .46	+ .47

Normal Equations.

$$5.20 \triangle\delta - 1.149\,\mu' + 2.240 = 0$$
$$- 1.149 \triangle\delta + .541\,\mu' + .251 = 0$$

$$\triangle\delta = - 1.005 \pm 155$$
$$100\,\mu' = - 2.599 \pm 481$$

Final Values.

$$\delta = 37° 59' 14''.70 \pm 15$$
$$\mu' = - .0260 \pm 48$$

78.

$\delta = 43^\circ\ 34'\ 18''.00.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Da, ...	3	.05	91	— .23	—1.90
Gr, ...	10	.3	65	+2.35	+1.21
Ah, . . .	3	.0	21	—5.20	[—5.44]
Gh 40, . .	10	1.0	35	+ .18	— .35
Re 45, . .	4	.4	31	+ .48	+ .03
Gh 45, . .	11	1.5	31	+ .28	— .17
Ms, ...	4	.3	25	+ .97	+ .64
Bs, .	3	1.0	9	— .02	— .02
Wn. T. C.,	2	.3	— 1	+ .30	+ .50

Normal Equations.

$$4.85\ \triangle\delta - 1.341\ \mu' - 1.847 = 0$$
$$-1.341\triangle\delta + .499\ \mu' + .771 = 0$$

$$\triangle\delta = -\ .181 \pm 243$$
$$100\ \mu' = -2.031 \pm 756$$

Final Values.

$\delta = 43^\circ\ 34\ \ 17''.82 \pm 24$

$\mu' = -.0203 \pm 76$

99.

$\delta = 18^\circ\ 49'\ 21''.30.$
$\mu' = -.018.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	5	0.2	120	+ .70	+ .79
Pi, . .	7	.1	75	— .48	— .49
W. B., .	. .	.05	50	—3.17	—3.23
Ms, . .	.	.2	40	— .31	— .40
Rü 36, .	4	.2	39	—1.03	—1.12
Ah, .	5	.2	23	— 57	— .69
Rü 50, .	1	.2	25	+1.46	+1.34
Re 62, .	1	.2	13	— .95	—1.09
Re 64, .	1	.2	11	+1 13	+ .98
Re 65, .	2	.2	10	+ .42	+ .27
Gh 64, .	3	1.0	9	+ .35	+ .20

Normal Equations.

$$2.75\ \triangle\delta - .752\triangle\mu' - 313 = 0$$
$$-\ .752\triangle\delta + .456\triangle\mu' + 033 = 0$$

$$\triangle\delta = +.171 \pm 249$$
$$100\triangle\mu' = +.214 \pm 305$$

Final Values.

$\delta = 18^\circ\ 49'\ 21''.47 \pm 25$

$\mu' = -.0159 \pm 30$

109.

$\delta = 29^\circ\ 3'\ 46''.40.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	4	.2	120	+5.64	+ .87
Pi, . .	7	.1	75	+ .17	—1.90
Ah, . .	6	.3	23	—2.14	—1.09
Gh 45, .	2	.4	30	—1.01	— .38
Gh 64, .	19	2.5	9	—1.62	+ .29
Gh 72, .	21	2.0	3	—2.33	— .05

Normal Equations.

$$5.50\ \triangle\delta - .789\ \mu' + 8.611 = 0$$
$$-\ .789\triangle\delta + .418\ \mu' + .593 = 0$$

$$\triangle\delta = -2.426 \pm 175$$
$$100\ \mu' = -5.993 \pm 637$$

Final Values.

$\delta = 29^\circ\ 3'\ 43''.97 \pm 17$

$\mu' = -.0599 \pm 64$

225

$\delta=83^{\circ}\ 1'\ 39''.80.$
$\mu'=-.02.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B,	5	.1	120	—1.18	+ .38
F. L. L,	2	.05	85	—3.68	—2.90
Sch.,	2	.1	47	+2.32	+2.26
Gh. 40,	9	1.0	35	+ .07	— .25
C,	3	.1	20	+2.34	+1.68
Re. 60,	2	3	15	+1.21	+ .44
Bs.,	3	6	14	+1.27	+ .48
Gh. 64,	5	1.5	11	+ .66	— .20
Gh. 72,	4	.8	3	+ .90	— .13
Wn. M. C.,	2	.1	1	+ .54	— .54

Normal Equations.

$$4.65\ \triangle\delta-.898\triangle\mu'-3.123=0$$
$$-.898\ \triangle\delta+.366\triangle\mu'+.176=0$$
$$\triangle\delta=+1.100\pm190$$
$$100\triangle\mu'=+2.217\pm677$$

Final Values.

$\delta=83^{\circ}\ 1'\ 40''.90\pm19$
$\mu'=+.0022\pm68$

235.

$\delta=50^{\circ}\ 53'\ 24''.40.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
F. L. L.,	3	.05	85	+1.27	—3.47
Pi,	6	.1	75	+5.37	+ .93
Gr.,	6	.2	65	+3.81	— .33
Ms.,	3	.1	40	+3.63	+ .24
Ah.,	4	.2	28	+3.23	+ .20
Re. 45,	5	.4	29	+3.98	+ .92
Bs.,	2	.8	8	+2.33	— .10
Wn.T.C.,	3	.4	2	+1.74	— .51

Normal Equations.

$$2.25\triangle\delta-.531\ \mu'-6.523=0$$
$$-.531\triangle\delta+.247\ \mu'+1.903=0$$
$$\triangle\delta=+2.194\pm280$$
$$100\ \mu'=-2.991\pm845$$

Final Values.

$\delta=50^{\circ}\ 53'\ 26''.59\pm28$
$\mu'=-.0299\pm84$

254.

$\delta=58^{\circ}\ 30'\ 20''.40.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Pi,	4	.1	75	+2.38	+ .24
Gr.,	6	.2	65	+1.65	+ .01
Ah.,	5	.2	24	— .88	—. 49
Re. 45,	4	4	26	— .35	— .06
Gh. 72,	3	.7	6	—1.15	+ .14

Normal Equations.

$$1.60\ \triangle\delta-.399\ \mu'+553=0$$
$$-.399\triangle\delta+.181\ \mu'+267=0$$
$$\triangle\delta=-1.584$$
$$100\triangle\mu'=-4.968$$

Final Values.

$\delta=58^{\circ}\ 30'\ 18''.82$
$\mu'=-.0497$

255.

$\delta = 59^\circ\ 41'\ 7''.60.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
F. L. L., .	1	.05	85	+2.63	+1.18
Gr, . . .	7	.3	62	+ .74	— .38
Re 45, . . .	4	.4	26	+ .59	+ .01
Ms, ...	4	.3	25	+ .92	+ .32
Bs, ...	1	.5	11	+ .29	— .02

Normal Equations.

$$1.55\ \triangle\delta - .462\ \mu' - 1.010 = 0$$
$$-\ .462\triangle\delta + .203\ \mu' +\ .395 = 0$$

$$\triangle\delta = +\ .223$$
$$100\ \mu' = -\ 1.440$$

Final Values.

$\delta = 59^\circ\ 41'\ 7''.82$
$\mu' = -.0144$

264.

$\delta = 22^\circ\ 44'\ 31''.94.$
$\mu' = -.0610.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	2	.1	120	— .00	— .02
Pi, . . .	9	.1	75	— .57	— .57
W. B., .	. .	.05	50	—1.20	—1.20
Ah, . .	2	.2	24	+1.38	+1.39
Gh 60, .	5	1.5	15	+ .06	+ .08
Gh 72, .	7	1.0	3	— .15	— .13
Wn M C,	3	.2	3	— .73	— .72

Normal Equations.

$$3.15\ \triangle\delta - .529\triangle\mu' + .047 = 0$$
$$-\ .529\triangle\delta + .262\triangle\mu' - .002 = 0$$

$$\triangle\delta = -\ .021 \pm .161$$
$$100\triangle\mu' = -\ .035 \pm .558$$

Final Values.

$\delta = 22^\circ\ 44'\ 31''.92 \pm 16$
$\mu' = -\ .0613 \pm 56$

305.

$\delta = 14^\circ\ 16'\ 24''.20.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	3	.1	120	—3.41	+ .76
Pi, . . .	10	.1	75	—4.46	—1.46
Ms, . .	5	.2	40	—2.02	+ .06
Ah, . .	2	.2	21	—1.74	— .16
Re, . .	3	.3	10	—2.03	— .74
Gh 64, .	3	1.0	11	— .90	+ .42
Gh 72, .	1	.5	2	—1.30	— .22

Normal Equations.

$$2.40\ \triangle\delta - .467\ \mu' + 3.698 = 0$$
$$-\ .467\triangle\delta + .256\ \mu' - 1.152 = 0$$

$$\triangle\delta = -\ 1.031 \pm 192$$
$$100\ \mu' = +\ 2.619 \pm 587$$

Final Values.

$\delta = 14^\circ\ 16'\ 23''.17 \pm 19$
$\mu' = +\ .0262 \pm 59$

361. $\delta = -7° 26' 49''.70$. $\mu' -.035$.

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, ...	3	.1	120	—1.47	—1.39
Pi, ...	6	.1	75	+ .03	+ .20
W. B., . .	. .	.05	50	—3.40	—3.17
Ah, ...	3	.2	23	—1.22	— .93
Ms, ...	4	.2	40	+1.95	+2.20
Ce 46, . . .	1	.3	29	+ .08	+ .35
Ce 45, . . .	4	1.0	30	+ .14	+ .44
Gh 64, . .	3	1.0	11	— .44	— .13
Re, ...	4	.4	10	—1.24	— .92

370. $\delta = 15° 28' 15''.00$.

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	3	.1	120	+5 06	+ .75
Pi, . . .	4	.1	75	+2.03	—1.11
Ah, . .	3	.2	23	+1.44	— .36
Gh 64, .	3	.8	7	+1.40	+ .02
Bs, . . .	2	.8	9	+1.55	+ .12

412. $\delta = 67° 28' 36''.10$.

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B, . . .	5	.2	120	—3.28	— .49
Pi, . . .	7	.1	75	—1.81	+ .08
Gr, . .	4	.2	65	—2.10	— .41
Bu, . .	6	.1	52	—1.11	+ .32
Pond, .	12	.8	45	—1.22	+ .08
Ms, . .	9	.2	43	—1.53	— .27
Rü, . .	4	.2	39	— .01	+1.16
Eh, . .	2	.6	35	— .92	+ .18
Ah, . .	5	.3	23	— .64	+ .22
Gh 40, .	4	.6	35	— .58	+ .52
Re 45, .	4	.4	30	— .79	+ .21
Re 58, .	4	.4	17	— .55	+ .19
Re 60, .	3	.3	15	— .62	+ .08
Gh 60, .	2	.7	15	—2.01	—1.31
Bs, . .	2	.5	13	— .79	— .13
Bs, . .	3	.6	10	— .36	+ .24
Gh 64, .	1	.4	11	— .88	— .26
Gh 72, .	3	.7	3	+ .07	+ .53
Dm, . .	.	.5	0	— .65	— .25
Gh 50, .	2	.3	23	—1.06	— .20

Normal Equations. $3.35 \triangle\delta - .883 \triangle\mu' + .940 = 0$ $- .883 \triangle\delta + .386 \triangle\mu' - .215 = 0$ $\triangle\delta = -.337 \pm .341$ $100 \triangle\mu' = -.214 \pm 1.003$	*Normal Equations.* $2.00 \triangle\delta - .369 \mu' - 3.357 = 0$ $-.369 \triangle\delta + .221 \mu' + 1.015 = 0$ $\triangle\delta = +1.201 \pm 153$ $100 \mu' = -2.587 \pm 459$	*Normal Equations.* $8.10 \triangle\delta - 2.107 \mu' + 7.430 = 0$ $-2.107 \triangle\delta + .954 \mu' - 2.740 = 0$ $\triangle\delta = - .400 \pm 092$ $100 \mu' = +1.988 \pm 359$
Final Values. $\delta = -7^\circ 26' 50''.04 \pm 34$ $\mu' = -.0371 \pm 100$	*Final Values.* $\delta = 15^\circ 28' 16''.20 \pm 15$ $\mu' = -.0259 \pm 46$	*Final Values.* $\delta = 67^\circ 28' 35''.70 \pm 09$ $\mu' = +.0199 \pm 36$

488. $\delta = 11^\circ\ 30'\ 5''.20$; $\mu' = +.032$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B., ...	5	.2	120	+ .57	+ .54
Pi., ...	22	.1	75	+ .13	+ .10
Da., . . .	3	.05	91	— 1.39	— 1.42
Pearson, .	8	.1	42	— .92	— .96
W. B., . .		.05	50	— .72	— .76
Ms., . . .	9	.2	40	— .06	— .10
Rü., . . .	3	.2	39	+ .87	+ .83
Ah., . . .	1	.1	22	+ 1.98	+ 1.94
Gh. 40, . .	5	.7	34	+ .11	+ .07
Gh. 45, . .	6	1.0	30	+ 1.20	+ 1.16
Ce., . . .	4	1.0	29	— 1.26	— 1.30
Gh. 60, . .	12	2.0	15	+ .09	+ .04
Re. 60, . .	4	.4	15	— .21	— .26
Bs., ...	2	.5	13	— .46	— .51
Ce. 60, .	2	.5	15	+ .78	+ .73
C. G. H. 60,	4	1.0	15	— .97	— 1.02
Re., . .	2	.2	10	— .92	— .97
Gh. 64, .	3	1.0	10	+ .33	+ .28
Wn. M. C.,	3	.5	15	+ .14	+ .09
Wn. T. C.,	3	.4	3	+ .72	+ .67
Gh. 72, . .	3	.7	3	+ .56	+ .51

515. $\delta = 59^\circ\ 55'\ 10''.40$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B., . . .	2	.1	120	+ 3.86	— .72
Pi., . .	6	.1	75	+ 3.39	+ .13
Gr., . .	5	.2	65	+ 4.66	+ 1.69
Ah., . .	5	.2	31	+ 1.62	— .36
Gh., . .	22	2.0	35	+ 1.91	— .19
Re. 45, .	10	.5	30	+ 2.06	+ .11
Re. 60, .	1	.2	15	+ 1.17	— .34
Bs., .	2	.8	7	+ 1.22	— .06
Gh. 72, .	6	1.0	3	+ 1.40	+ .24

533. $\delta = 19^\circ\ 27'\ 30''.80$; $\mu' = -.08$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B., . . .	5	.2	120	+ 1.50	+ .09
Pi., . .	9	.1	75	+ .17	— .10
W. B., .		.05	50	— 1.51	— 1.15
Ah., .	5	.2	23	— 1.95	— .96
Gh. 60, .	3	1.0	19	— .82	+ .31
Bs.,	1	.5	6	— 1.60	— .13
Wn. M. C.	2	.2	7	— 1.60	— .15

Normal Equations. $10.90\ \triangle\delta - 2.314\triangle\mu' - .488 = 0$ $-2.314\triangle\delta + .856\triangle\mu' + .097 = 0$ $\triangle\delta = +.049 \pm 173$ $100\triangle\mu' = +.018 \pm 617$	*Normal Equations.* $5.10\ \triangle\delta - 1.353\mu' - 9.441 = 0$ $-1.353\triangle\delta + .602\mu' + 3.214 = 0$ $\triangle\delta = +1.076 \pm 158$ $100\mu' = -2.918 \pm 461$	*Normal Equations.* $2.25\ \triangle\delta - .620\triangle\mu' + 2.089 = 0$ $-.620\triangle\delta + .406\triangle\mu' + .019 = 0$ $\triangle\delta = -1.626 \pm 157$ $100\triangle\mu' = -2.528 \pm 369$
Final Values. $\delta = 11^\circ\ 30'\ 5''.25 \pm 17$ $\mu' = +.0322 \pm 62$	*Final Values.* $\delta = 59^\circ\ 55'\ 11''.48 \pm 16$ $\mu' = -.0292 \pm 46$	*Final Values.* $\delta = 19^\circ\ 27'\ 29''.17 \pm 16$ $\mu' = -.1053 \pm 37$

556.

$\delta = 21° 39' 13''.74$
$\mu' = +.0060$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Pi.,	7	.1	75	+ .93	+ .49
Da.,	4	.05	75	+ .09	— .53
W. B.,		.05	50	— 1.25	— 1.38
Gh. 64,	4	1.0	11	— .13	+ .23
Bs.,	2	.8	9	— .58	— .19
Wn. M.C.,	2	.1	5	— .86	— .42

Normal Equations.

$$2.10\ \triangle\delta - .325\triangle\mu' + .645 = 0$$
$$-\ .325\triangle\delta + .115\triangle\mu' - .018 = 0$$

$$\triangle\delta = -\ .503$$
$$100\triangle\mu' = -1.261$$

Final Values.

$\delta = 21° 39' 13''.24$
$\mu' = -\ .0066$

629.

$\delta = 10° 24' 55''.18$
$\mu' = -.0178$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Pi.,	8	.1	75	— .71	— .53
Ah.,	2	.2	22	+ 1.67	+ 1.69
Re.,	1	.2	15	— .80	— .80
Bs.,	2	.8	9	— .14	— .16

Normal Equations.

$$1.30\ \triangle\delta - .221\triangle\mu' + .009 = 0$$
$$-\ .221\triangle\delta + .076\triangle\mu' - .013 = 0$$

$$\triangle\delta = +.043$$
$$100\triangle\mu' = +.300$$

Final Values.

$\delta = 10° 24' 55''.22$
$\mu' = -\ .0148$

632.

$\delta = 17° 39' 5''.40$
$\mu' = -.0205$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
Pi.,	6	.1	75	+ .23	+ .05
W. B.,	.	.05	50	— 1.83	— 1.95
Ah.,	2	.2	22	+ 1.28	+ 1.23
Gh. 60,	4	1.0	15	+ .20	+ .17
Gh. 64,	7	1.5	11	— .06	— .09
Gh. 72,	7	1.0	3	— .02	— .02
Bs.,	3	1.0	11	— .14	— .17

Normal Equations.

$$4.85\ \triangle\delta - .599\triangle\mu' - .137 = 0$$
$$-\ .599\triangle\delta + .132\triangle\mu' + .031 = 0$$

$$\triangle\delta = -.002 \pm 153$$
$$100\triangle\mu' = -.241 \pm 929$$

Final Values.

$\delta = 17° 39\ 5''.45 \pm 15$
$\mu' = -.0229 \pm 93$

706.

$\delta = 46^\circ\ 48'\ 6''.27.$
$\mu' = -.033$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B.,	3	.1	120	+ .35	+ .75
Pi.,	5	.1	75	—1.45	—1.21
Gr.,	5	.2	65	— .55	— .34
Ah.,	5	.3	29	+ .17	+ .25
Ms.,	4	.2	40	+ .65	+ .77
Re. 45,	3	.3	30	+ .24	+ .33
Gh. 45,	6	1.0	30	— .38	— .29
Ms.,	4	.3	25	+ .20	+ .27

Normal Equations.

$$2.50\ \triangle\delta - .957\ \triangle\mu' + .287 = 0$$
$$-\ .957\ \triangle\delta + .477\ \triangle\mu' - .149 = 0$$

$$\triangle\delta = +.020 \pm 253$$
$$100\ \triangle\mu' = +.352 \pm 459$$

Final Values.

$\delta = 46^\circ\ 48'\ 6''.29 \pm 25$

$\mu' = -.0295 \pm 46$

780.

$\delta = 14^\circ\ 28'\ 47''.60.$
$\mu' = +.022.$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B.,		.1	120	+ .27	+ .53
Pi.,		.1	75	— .63	— .41
W. B.,		.05	50	—1.00	— .79
Da.,		.05	90	— .71	— .47
Ms.,	5	.2	40	+ .68	+ .88
Rü.,	2	.2	39	— .96	— .76
Ah.,	5	.3	22	+ .74	+ .93
Ce. 44,	2	.5	31	— .64	— .44
Bs.,	1	.5	8	— .73	— .55
Gh. 40,	6	.8	34	— .15	+ .05
Gh.,	5	1.0	7	+ .03	+ .21

Normal Equations.

$$3.80\ \triangle\delta - 1.026\ \triangle\mu' + .731 = 0$$
$$-1.026\ \triangle\delta + .478\ \triangle\mu' - .211 = 0$$

$$\triangle\delta = -.174 \pm 168$$
$$100\ \triangle\mu' = +.068 \pm 473$$

Final Values.

$\delta = 14^\circ\ 28'\ 47''.43 \pm 17$

$\mu' = +.0227 \pm 47$

816.

$\delta = 54^\circ\ 34'\ 15''.20.$
$\mu' = -.024$

Authority.	No. of Obs.	Wt.	1875—t.	O—C.	v.
B.,	4	.2	120	— .42	+ .14
Pi.,	6	.1	75	+ .78	+1.08
Gr.,	6	.3	66	— .83	— .58
Ms.,	4	.2	40	+ .05	+ .15
O. Arg.,		.1	33	— .95	— .89
Ah.,	5	.3	33	+1.42	+1.48
Re. 45,	4	.4	31	—1.42	—1.37
Gh. 64,	3	1.0	8	+ .37	+ .28
Bs.,	1	.3	11	+ .55	+ .48
Wn.T.C,	5	.4	7	— .46	— .55

Normal Equations.

$$3.30\ \triangle\delta - .990\ \triangle\mu' + .131 = 0$$
$$-\ .990\ \triangle\delta + .632\ \triangle\mu' - .234 = 0$$

$$\triangle\delta = +.135 \pm 251$$
$$100\ \triangle\mu' = +.581 \pm 570$$

Final Values.

$\delta = 54^\circ\ 34'\ 15''.33 \pm 25$

$\mu' = -.0182 \pm 57$

897.

$\delta = 46° 39' 19 .90.$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
Gr.,	6	.3	64	+ .27	— .33
Re. 45,	6	.5	31	+ .22	— .21
Ms.,	5	.3	25	+2.06	+1.67
Bs.,	2	.8	10	+ .08	— .24
Gh.64,	5	1.5	10	+ .25	— .07

Normal Equations.

$$3.40\,\triangle\delta - .652\mu' - 1.248 = 0$$
$$-.652\triangle\delta + .213\mu' + .285 = 0$$

$$\triangle\delta = +.268$$
$$100\mu' = -.519$$

Final Values.

$\delta = 46° 39' 20''.17$
$\mu' = -.0052$

915.

$\delta = 34° 40' 49''.37.$
$\mu' = -.0025.$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
Pi.,	5	.1	75	—1.01	—.98
W. B.,		.05	50	+ .10	+.12
Ah.,	2	.2	28	+ .72	+.73
Wn.P.V,	1	.2	27	+ .83	+.84
Wn T.C.,	3	1.0	7	— .22	—.22

Normal Equations.

$$1.55\triangle\delta - .280\triangle\mu' - .006 = 0$$
$$-.28\triangle\delta + .105\triangle\mu' - .003 = 0$$

$$\triangle\delta = +.002$$
$$100\triangle\mu' = +.035$$

Final Values.

$\delta = 34° 40' 49''.37$
$\mu' = -.0022$

950.

$\delta = 3° 51' 30''.50$

Authority.	No. of Obs.	Wt.	1875—t.	O-C.	v.
B.,	3	.1	120	+ .74	+ .33
Pi.,	5	.1	75	+ .20	— .06
W. B.,		.05	50	—1.66	—1.83
Ah.,	5	.3	33	+ .04	— .07
Gh. 64,	2	.7	11	+ .10	+ .06
Bs.,	3	1.0	9	+ .07	+ .04

Normal Equations.

$$2.25\,\triangle\delta - .486\mu' - .163 = 0$$
$$-.486\triangle\delta + .338\mu' + .116 = 0$$

$$\triangle\delta = -.002$$
$$100\mu' = -.347$$

Final Values.

$\delta = 3° 51' 30''.50$
$\mu' = -.0035$

The pages which follow contain the adopted mean declinations of all stars used in the latitude determination. They are written in pairs as they were arranged for observation with the Zenith Telescope and are reduced to the mean epoch 1875.0. The column headed B. A. C. contains the numbers of the stars in the British Association Catalogue. The magnitudes are those of the B. A. C. The right ascensions are only approximate but sufficiently accurate for the purpose, $\frac{d\alpha}{dt}$ includes proper motion when it could be ascertained with any approach to accuracy. $\frac{d^2\alpha}{dt^2}$ is given in units of the fifth place. $\frac{d\delta}{dt}$ includes the value of the proper motion given in the last column but one. $\frac{d^2\delta}{dt^2}$ is given in units of the sixth place. $\frac{d^3\delta}{dt^3}$ is in units of the eighth place.

Let α_0 & δ_0 be the right ascension and declination of any star for 1875.0.

α & δ be the right ascension and declination of the same star for 1875+t.

t being expressed in years

Then $\alpha = \alpha_0 + \frac{d\alpha}{dt} t + \frac{d^2\alpha}{dt^2} \frac{t^2}{2}$.

$$\delta = \delta_0 + \frac{d\delta}{dt} t + \frac{d^2\delta}{dt^2} \frac{t^2}{2} + \frac{d^3\delta}{dt^3} \frac{t^3}{6}.$$

For example let the formulæ be applied to the first star on the list :

$$\alpha = 17^h\ 43^m\ 45^s.0 + 2^s.430t + .00003 \frac{t^2}{2}.$$

$$\delta = 25°\ 39'\ 56''.97 - 1''.4703t + .003538 \frac{t^2}{2} + .00000005 \frac{t^3}{6}.$$

Mean places for 1875.0 of Stars used in determining Latitude of Wilkes Barre.

B. A. C.	NAME.	Magnitude.	Approximate Right Ascension 1875.0	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	Declination 1875.0	Probable error.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ	Probable error.
			h. m. s.			° ′ ″						
6033	87 Herculis, ...	6	17 43 45.0	+2.430	+ 3	25 39 56 97	18	— 1.4703	+3538	+ 5	— .0497	57
6079	ξ Draconis, ...	3.5	17 51 22.1	+1.036	+ 4	56 53 34.27	16	— .6840	+1530	+ 4	+ .0712	48
6123	70 Ophiuchi, ...	4.5	17 59 8 2	+3.013	+ 3	2 31 49.19	24	— 1.2129	+4395	+ 1	—1.1374	88
6206	40 Draconis, ...	5	18 9 23.4	—4.470	—26	79 58 54.77	21	+ .9408	—6486	—44	+ .1194	62
6421	. . . .	6	18 44 16.0	+1.547	0	49 17 39 20	30	+ 3 8772	+2198	— 6	+ .0278	109
6429	β Lyræ, ...	3	18 45 27.9	+2.214	+ 1	33 13 7.21	6	+ 3.9352	+3150	—11	— .0171	25
6468	. . . .	6	18 50 17.8	+2.198	+ 1	33 48 36.91	21	+ 4.3472	+3110	—12	— .0186	64
6476	. . . .	6	18 51 29.3	+1.580	0	48 42 14.32	56	+ 4.3480	+2216	— 8	— .1196	131
6553	17 Lyræ, ...	6	19 2 42.0	+2.266	+ 1	32 18 21.38	23	+ 5.4360	+3170	—16	+ .0178	64
6566	. . . .	7	19 5 21.6	+1.534	— 1	50 9 45.90	46	+ 5.6192	+2123	—10	— .0228	137
6583	53 Draconis, . . .	5	19 9 18.7	+1.133	— 5	56 38 48.57	18	+ 6.0108	+1552	—12	+ .0379	45
6637	3 Vulpeculæ, ...	6	19 17 43.8	+2.457	+ 1	26 1 25.64	32	+ 6.6558	+3350	—22	— .0162	123
6690	β Cygni, ...	3	19 25 40.8	+2.417	+ 1	27 41 54.06	9	+ 7.3094	+3247	—24	— .0144	38
6748	. . . .	5	19 35 52.7	+1.356	— 4	54 40 52.85	35	+ 8.3070	+1783	—15	+ .160	170
6830	. . . .	6	19 48 26.2	+1.763	0	47 36 34.95	24	+ 9.1196	+2256	—18	— .0188	95
6851	η Cygni, ...	5	19 51 36.9	+2.253	+ 1	34 45 7.71	19	+ 9.3414	+2863	—26	— .0438	58
6933	θ Sagittæ, ...	6.5	20 4 25.9	+2.643	0	20 32 41.22	26	+10.4517	+3256	—41	+ .0906	73
6970	68 Draconis.	6	20 09 31.9	+ .992	—14	61 42 1.60	26	+10.8185	+1196	—24	+ .0779	76

7022	γ Cygni, ...	3	20 17 44.5	+2.152	+ 2	39	51	26.82	9	+11.3333	+2539	—28	— .0069	26
7100	. . . .	6	20 28 31.3	+2.086	+ 2	42	46	0.62	. . .	+12.1784	+2374	—28	+ .073	
7166	. . . . .	6	20 35 46.3	+1.560	— 3	55	33	52.71	. . .	+12.5450	+1711	—22	— .060	
7246	31 Vulpeculæ, . .	6	20 46 46.7	+2.572	+ 2	26	37	47.88	. . .	+13.2590	+2743	—46	— .0803	
7273	. . . .	6	20 52 10.2	+2.114	+ 3	44	26	40 68		+13.6757	+2194	—31	— .0122	
7320	. . . .	6.5	20 58 13.9	+2.323	+ 4	38	9	50.69	24	+14.0641	+2354	—38	— .0066	92
	Fed (3689), ...	. .	21 1 33.6	+1.462	— 6	59	45	31.97		+14.2617	+1436	—23	— .015	
7361	. . . .	8	21 6 18.9	+2.690	+ 2	22	34	13.57		+14.4758	+2634	—56	— .090	
7398	σ Cygni, ...	4.5	21 12 30.4	+2.353	+ 5	38	52	17.47	13	+14.9311	+2226	—41	— .0017	43
7402	A Cygni, ...	6	21 13 47.4	+2.233	+ 5	43	25	13 80	45	+14.9779	+2096	—36	— .0296	150
7462	70 Cygni, ...	5½	21 22 15.6	+2.442	+ 6	36	34	27.19	14	+15.4888	+2196	—45	— .0065	60
7480	71 Cygni, ...	5	21 24 50.2	+2.209	+ 6	45	59	24.26	19	+15.7294	+1953	—36	+ .0984	52
7521	74 Cygni, ...	6	21 31 56.4	+2.400	+ 7	39	51	9.77	24	+16.0117	+2039	—44	— .0002	59
7544	75 Cygni, ...	6	21 35 16.8	+2.344	+ 8	42	42	24.93	30	+16.1871	+1948	—42	+ .0033	86

Mean places of Stars used in determining Latitude of Wilkes Barre.

B. A. C.	NAME.	Magnitude.	Approximate Right Ascension 1875.0. h. m. s.	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	Declination 1875.0. ° ′ ″	Probable error.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ	Probable error.
7585	12 Pegasi, ...	6.	21 40 19.6	+2.757	+ 4	22 22 23 04	25	+16.4063	+2231	— 65	—.0375	85
7605	12 Cephei, ...	6.	21 43 44.0	+1.766	+ 3	60 06 46.94	30	+16.6117	+1374	— 26	—.0010	79
7627	16 Pegasi, ...	5.5	21 47 22.5	+2.727	+ 5	25 20 15.72	8	+16.7769	+2102	— 64	—.0121	49
7668	. . . .	6.5	21 55 12.0	+2.003	+ 9	57 3 37.50	24	+17.1431	+1440	— 31	—.0106	65
7706	ι Pegasi, ...	4.	22 1 11.6	+2.789	+ 6	24 44 6.85	13	+17.4253	+1955	— 69	+.0059	43
7749	ζ Cephei, ...	4.	22 6 31.2	+2.073	+ 11	57 35 7.92	10	+17.6493	+1361	— 34	+.0037	32
7824	. . . .	6.5	22 20 3.1	+2.384	+ 16	50 37 15.48		+18.2088	+1391	— 46	+.0316	
7843	38 Pegasi, ...	6.	22 24 18.9	+2.738	+ 11	31 56 0 28	18	+18.3128	+1542	— 69	—.0189	69
7932	13 Lacertæ, ...	6.	22 38 31.1	+2.665	+ 16	41 9 49.35	33	+18.8001	+1272	— 64	+.0010	83
7962	14 Lacertæ, ...	6.	22 44 43.7	+2.694	+ 17	41 17 31.12	30	+18.9721	+1185	— 66	—.0102	76
8024	. . . .	6.5	22 56 14.0	+2.519	+ 26	56 26 2.61	33	+19.2638	+ 926	— 55	—.0191	134
8079	60 Pegasi, ...	6.	23 5 45.3	+2.905	+ 12	26 10 20.48	17	+19.3576	+ 905	— 83	—.1375	59
8118	9 Andromedæ, . . .	6.	23 12 27.7	+2.832	+ 21	41 5 28.22	17	+19.6087	+ 766	— 78	—.0156	46
8128	10 Andromedæ, . . .	6.	23 13 55.7	+2.842	+ 21	41 23 38.04	26	+19.6509	+ 742	— 78	—.0005	67
8177	θ Piscium, ...	5.	23 21 37.6	+3.041	+ 3	5 41 33.03	12	+19.7175	+ 652	— 96	—.0563	39
8238	γ Cephei, ...	3.	23 34 13.8	+2.405	+ 73	76 56 4.87	7	+20.0711	+ 304	— 49	+.1435	22
8293	80 Pegasi, ...	7.	23 44 58.7	+3.059	+ 6	8 37 13.91	. .	+19.9375	+ 206	— 99	—.0736	
8314	. . . .	5.	23 48 46.3	+2.850	+ 88	73 42 53.04	13	+20.0211	+ 117	— 80	—.0090	66

16	22 Andromedæ. . . .	5.	0 3 49.8	+3.095	+ 33	45	22	35.63	18	+20.0514	— 162	—102	—.0039	40
67	ρ Andromedæ, ...	5 5	0 14 32.4	+3 141	+ 26	37	16	33.11	10	+19.9469	— 376	—109	—.0670	50
109	28 Andromedæ, . . .	6.	0 23 31.7	+3.148	+ 21	29	3	43.97	17	+19.8888	— 556	—107	—.0599	64
153	ζ Cassiopeæ, ...	4.	0 30 1.0	+3.309	+ 49	53	12	30.94	13	+19.8621	— 716	—124	—.0204	41
255	. . . . . .	6.	0 49 15.8	+3.560	+ 70	59	41	7.82	. .	+19.5783	—1192	—152	—.0144	
264	η Andromedæ, . . .	5.	0 50 32.3	+3.195	+ 18	22	44	31.92	16	+19.5073	—1103	—110	—.0613	56
	LL. (1985), ...	.	1 2 25.9	+3.966	+113	67	6	43.88	. .	+19.3167	—1655	—205	+.0002	
370	87 Piscium, ...	6.5	1 7 29.3	+3.180	+ 14	15	28	16.20	15	+19.1651	—1428	—107	—.0259	46
412	ψ Cassiopæ, ...	4 5	1 17 7.6	+4.137	+121	67	28	35.70	9	+18.9492	—2074	—228	+.0199	36
453	η Piscium, ...	4.	1 24 47.7	+3.199	+ 14	14	42	2.65	8	+18.6898	—1768	—107	—.0074	35
533	109 Piscium, ...	6.5	1 38 6.2	+3.265	+ 17	19	27	29.17	16	+18.1395	—2053	—112	—.1053	37
564	ε Cassiopæ, ...	3.	1 45 25.4	+4.245	+ 99	63	3	11.63	11	+17.9450	—2828	—234	—.0247	34
600	50 Cassiopeæ, ...	4.	1 52 47.9	+4.984	+186	71	48	53.84	10	+17.6975	—3503	—357	+.0235	36
629	. . . .	7.	1 56 17.9	+3.198	+ 13	10	24	55.22	. . .	+17.5124	—2346	—102	—.0148	

Mean places for 1875.0 of stars used in determining Latitude of Pottsville.

B. A. C.	NAME.	Magnitude.	Approximate right ascension 1875.0. h. m. s.	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	Declination 1875.0. ° ′ ″	Probable error.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.	Probable error.
7561	ε Pegasi, ...	2.5	21 38 2.8	+2.948	— 1	9 18 10.14	7	+ 16.3231	+2428	— 78	—.0058	31
7597	78 Draconis, ...	5.	21 41 32.1	+ .757	—41	71 44 50.14	20	+ 16.4601	+ 546	— 39	—.0432	56
7627	16 Pegasi, ...	5.5	21 47 22.5	+2.727	+ 5	25 20 15.72	8	+ 16.7769	+2102	— 64	—.0121	49
7643	μ Cephei, ...	5.5	21 50 41.2	+2.010	+ 8	56 1 11.95	40	+ 16.9490	+1494	— 31	+.0032	113
7679	. . . .	6.	21 57 36.6	+2.458	+10	42 12 42.76	. .	+ 17.2950	+1748	— 49	+.033	
7765	. . . .	5.	22 8 30.9	+2.568	+11	39 5 43.24	20	+ 17.7168	+1672	— 56	—.0112	59
7931	. . . .	6.	22 38 26.8	+2.698	+15	38 48 38.96	43	+ 18.7734	+1290	— 66	—.0245	124
7972	15 Lacertæ, ...	5.5	22 46 23.9	+2.684	+18	42 38 53.86	14	+ 19.0290	+1153	— 65	—.0013	52
7984	. . . .	6.	22 48 22.9	+2.731	+17	39 42 38.13	50	+ 19.0830	+1142	— 69	+.0135	170
8023	o Andromedæ, . . .	4.	22 56 10.4	+2.747	+19	41 39 15.78	12	+ 19.2431	+1019	— 70	—.0384	43
8052	56 Pegasi, ...	4.5	23 1 1.5	+2.914	+11	24 47 38.02	19	+ 19.3519	+ 998	— 84	—.0421	72
8083	. . . .	6.	23 7 16.2	+2.861	+37	56 28 41.74	22	+ 19.7947	+ 919	— 79	+.2689	76
8138	. . . .	7.	23 15 7.5	+2.593	+37	61 31 44.76	. .	+ 19.6952	+ 651	— 60	+.0242	
8147	. . . .	6.5	23 16 32.3	+2.981	+10	19 52 26.48	38	+ 19.6947	+ 725	— 91	—.0168	218
8195	14 Andromedæ, . .	6.	23 25 8.8	+2.933	+21	38 32 59.21	18	+ 19.7377	+ 568	— 87	—.0851	44
8229	ι Andromedæ. . . .	4.	23 32 0.6	+2.923	+25	42 34 34.26	13	+ 19.8999	+ 434	— 86	—.0050	50
8272	. . . .	7.	23 41 49.2	+3.057	+ 5	7 33 6.94	20	+ 19.9621	+ 267	— 98	—.0290	113
8314	. . . .	5.	23 48 46.3	+2.850	+88	73 42 53.04	13	+ 20.0211	+ 117	— 80	—.0090	66

8330	σ Cassiopeæ, ...	5.5	23 52 40.5	+3.011	+43	55 3 33.59	35	+ 20.0440	+ 54	— 94	+.0018	76
8350	85 Pegasi, ...	6.	23 55 38.8	+3.126	+17	26 25 13.33	34	+ 19.0781	+ 2	— 105	—.9725	138
8373	10 Cassiopeæ, ...	6.	23 59 57.7	+3.072	+62	63 30 1.21	19	+ 20.0542	— 76	— 100	+.0003	51
8	87 Pegasi, ...	6.	0 2 35.7	+3.077	+11	17 31 1.25	14	+ 20.0243	— 137	— 100	—.0286	57
52	θ Andromedæ, . . .	5.	0 10 33.9	+3.120	+27	37 59 14.70	15	+ 20.0069	— 296	— 105	—.0260	48
78	. . . .	5.5	0 17 26.6	+3.169	+33	43 34 17.82	24	+ 19.9759	— 437	— 110	—.0203	76
99	46 Piscium, ...	6.5	0 21 28.2	+3.113	+13	18 49 21.47	25	+ 19.9504	— 510	— 104	—.0159	30
126	κ Cassiopeæ, ...	4.	0 25 54.5	+3.358	+70	62 14 29.68	21	+ 19.9227	— 638	— 130	—.0077	57
166	δ Andromedæ, . . .	3.	0 32 38.8	+3.192	+22	30 10 35.27	19	+ 19.7476	— 748	— 111	—.1035	55
235	. . . .	6.5	0 44 26.9	+3.389	+48	50 53 26.59	28	+ 19.6483	—1037	— 132	—.0299	84

Mean places for 1875.0 of Stars used in determining Latitude of Pottsville.

B. A. C.	NAME.	Magnitude.	Approximate Right ascension 1875.0	$\frac{d\alpha}{dt}$	$\frac{d^2\alpha}{dt^2}$	Declination 1875.0	Probable error.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ	Probable error.
			h. m. s.			° ′ ″						
254	v^2 Cassiopeæ, . .	5.5	0 49 14.3	+ 3.537	+ 66	58 30 18.82	. . .	+19.5435	—1184	— 149	—.0497	
264	η Andromedæ, . .	5	0 50 32.3	+ 3.194	+ 18	22 44 31.92	16	+19.5073	—1103	— 110	—.0613	56
305	72 Piscium, ...	6	0 58 29.7	+ 3.158	+ 13	14 16 23.17	19	+19.4308	—1246	— 106	+.0262	59
	LL (1985), ...	. . .	1 2 25.9	+ 3.966	+ 113	67 6 43.88	. . .	+19.3167	—1655	— 205	+.002	
361	36 Ceti, ...	7	1 6 30.3	+ 3.020	+ 2	—7 26 50.04	34	+19.1787	—1342	— 92	—.0371	100
360	α Ursæ Minoris, .	2	1 13 0.2	+20.868	+15068	88 38 33.86	3	+19.0458	—9670	—11308	+.0004	10
438	38 Cassiopeæ, . .	5	1 21 57.4	+ 4.357	+ 144	69 37 12.89	17	+18.7100	—2318	— 261	—.0756	57
488	π Piscium, ...	5	1 30 28.4	+ 3.170	+ 12	11 30 5.25	17	+18.5440	—1854	— 104	+.0322	62
515	44 Cassiopeæ, . .	6	1 34 53.1	+ 4.001	+ 82	59 55 11.48	16	+18.3307	—2426	— 201	—.0292	46
556	1 Arietis, ...	6	1 43 14.6	+ 3.312	+ 19	21 39 13.24	. . .	+18.0535	—2187	— 115	—.0066	
611	53 Cassiopeæ, . .	6	1 53 46.4	+ 4.365	+ 11	63 47 6.78	32	+17.6469	—3108	— 248	+.0135	79
632	. . . .	6	1 56 51.7	+ 3.280	+ 17	17 39 5.45	15	+17.4802	—2410	— 109	—.0229	93
656	β Trianguli, . .	4	2 2 6.7	+ 3.550	+ 30	34 23 41.73	11	+17.2248	—2714	— 136	—.0496	37
706	*c* Andromedæ, . .	6	2 11 13.4	+ 3.839	+ 48	46 48 6.29	25	+16.8263	—3103	— 166	—.0295	46
744	ι Cassiopeæ, . . .	4	2 18 47.5	+ 4.844	+ 131	66 50 19.27	11	+16.4926	—4097	— 310	+.0047	43
780	29 Arietis, . . .	6.5	2 26 3.4	+ 3.274	+ 151	14 28 47.43	17	+16.1405	—2907	— 102	+.0227	47

816	11 Persei, ...	6.5	2 34 6.9	+ 4.250	+ 66	54 34 15.33	25	+15.6701	—3934	— 206	—.0182	57
872	41 Arietis, ...	3	2 42 37.8	+ 3.514	+ 23	26 44 37.79	11	+15.0941	—3407	— 118	—.1195	42
897	. . . .	6	2 48 7.0	+ 4.021	+ 46	46 39 20.17	. . .	+14.8964	—3990	— 169	—.0052	
915	24 Persei, ...	5.5	2 51 19.3	+ 3.701	+ 29	34 40 49.37	. . .	+14.7072	—3733	— 132	—.0022	
950	93 Ceti, ...	6.5	2 55 49.6	+ 3.135	+ 10	3 51 30.50	. .	+14.4363	—3235	— 82	—.0035	
979	. . . .	5.5	3 4 32.1	+ 7.360	+ 353	77 16 19.19	11	+13.8452	—7819	— 763	—.0519	51

Computation of Latitude.

A few of the stars used are found in the American Ephemeris, in which case the apparent declinations are taken from that publication. In other cases they are reduced by the formula:

$$\delta = \delta_0 + \tau\mu' + g \cos (G+\alpha) + h \cos (H+\alpha) \sin \delta + i \cos \delta$$

The formula for the latitude will then be:

$$\phi = \tfrac{1}{2}(\delta+\delta') + \tfrac{1}{2}(M - M')\, R + \tfrac{1}{4}\Big((n+n') - (s+s')\Big) b + \tfrac{1}{2}\,(r - r')$$

In which δ & δ' are the apparent declinations of the two stars forming the pair.

M & M' the readings of the micrometer.
$n.s.\ n'.s.'$ the readings of the level.
$r.$ & $r'.$ the refractions.
$R.$ the value of one revolution of the micrometer screw.
$b.$ the value of one division of the level.

The final result given is the arithmetical mean of the individual determinations.

At Wilkes Barre one observation was made on the pair B. A. C. 204—225 which was not utilized, as I had no data for a satisfactory determination of the declination of 204. Also one observation at Pottsville on the pair 7679—7765 was rejected on account of the note—"very poor" in the original record. Besides these nothing has been suppressed.

The probable error of the resulting latitude was computed by the formula:

$$r = .6745 \sqrt{\frac{[vv]}{n(n-1)}}$$

where n is the number of observations.

The details are given in the following pages.

Latitude of Wilkes Barre.

B. A. C.	Micrometer.	Level. N.	Level. S.	Declination.	Corrections. Micrometer.	Corrections. Level.	Corrections. Ref.	Latitude.	Remarks.
				° ′ ″	′ ″	″	″	° ′ ″	
7166	12.511	16.0	20.6	55 35 27.66					
7246	29.532	25.6	11.0	26 39 28.16	+7 9.35	+2.65	+.14	41 14 40.05	August 10.
7273	27.230	18.0	19.0	44 28 22.74					
7320	14.610	21.0	16.2	38 11 35.46	—5 18.34	+1.01	—.09	41.68	
7398	26.082	16.9	20.6	38 54 7.38					
7402	16.330	19.2	18.3	43 27 3.58	+4 5.99	— .74	+.07	40.80	
7462	15.932	21.1	16.7	36 36 20.60					
7480	25.642	14 2	23.5	46 1 18.26	—4 4.93	—1.30	—.07	43.13	
7521	15.777	22.1	15.6	39 53 5.93					
7544	25.425	14.4	23.7	42 44 21.90	—4 3.37	— .74	—.07	39.74	
7585	17.573	22.5	15.7	22 24 23.19					
7605	22.060	12.7	25.4	60 8 44.13	—1 53.18	—1.56	—.04	38.88	
7627	21.194	14.3	24.0	25 22 15.10					
7668	19.605	27.7	10.6	57 5 37.86	+ 40.08	+1.96	+.01	38 53	
7706	24.413	19.0	19.0	24 46 12.96					
7749	17.386	20.6	18.0	57 37 10.86	+2 57.26	+ .69	+.06	39.92	
7824	25.815	18.1	21.0	50 39 22.31					
7843	15.996	25.7	13.8	31 58 10.47	—4 7.68	+2.38	—.07	41.02	
7932	19.090	15.0	24.8	41 12 0.61					
7962	21.880	22.7	17.1	41 19 43.18	—1 10.38	—1.11	—.02	40.39	

Latitude of Wilkes Barre—Continued.

B. A. C.	Micrometer.	Level. N.	Level. S.	Declination.	Corrections. Micrometer.	Corrections. Level.	Corrections. Ref.	Latitude.	Remarks.
				° ′ ″	′ ″	″	″	° ′ ″	
8024	27.310	20.7	20.0	56 28 13.23					
8079	13.644	16.6	24.0	26 12 37.07	—5 44.72	—1.78	—.10	41 14 38.55	
8118	18.251	24.1	16.2	41 7 43.13					
8128	23.253	16.1	24.9	41 25 53.31	—2 6.18	— .24	—.03	41.77	
8177	12.659	20.4	20.6	5 43 55.78					
8238	27.917	18.1	22.6	76 58 14.75	—6 24.88	—1.25	—.16	38.97	
8293	22.675	11.3	13.0	8 39 37.14					
8314	17.041	12.1	12.1	73 45 2.09	+2 22.12	— .45	+.04	41.33	
16	28.406	9.4	15.1	45 24 49.78					
67	11.410	15.4	9.4	37 18 48.10	—7 8.72	+ .08	—.12	40.18	
109	26.208	12.8	12.1	29 6 0.41					
153	15.893	8.3	17.1	53 14 40.47	+4 20.20	—2.15	+.07	38.56	
255	20.325	9.3	15.9	59 43 12.82					
264	19.589	15.8	9.6	22 46 46.67	— 18.57	— .11	.0	41.07	
L.L.	25.935	12.7	12.8	67 8 44.71					L.L. 1985.
370	14.150	12.1	13.1	15 30 30.39	—4 57.28	— .29	—.10	39.88	
412	11.293	14.8	10.8	67 30 33.18					
453	28.667	9.3	16 1	14 44 13.42	+7 18.26	— .74	+.15	40.93	
533	16.180	11.1	14.8	19 29 34.31					
564	22.397	13 0	12.9	63 5 2.00	—2 36.82	— .95	—.05	40.34	August 10.

600	11.928	13.7	12.1	71	50	40.30						
629	25.883	12.1	13.9	10	26	59.65	+5	52.01	— .05	+.13	42.07	
6033	17.917	18.3	11.0	25	40	1.36						
6079	23.235	14.1	15.2	56	53	47.69	—2	14.15	+1.64	—.04	41.97	August 12.
6123	19.370	14.1	15.3	2	31	50.41						
6206	21.749	14.6	15.1	79	59	18.21	—1	0.01	— .45	—.02	33.83	Rejected.
6421	21.479	15.0	15.9	49	18	21.43						
6429	18.231	14.8	16.1	33	13	48.45	—1	21.93	— .58	—.03	42.40	
6468	19.859	16.5	14.6	33	49	20.98						
6476	23.367	9.4	21.8	48	42	59.47	—1	28.31	—2.78	—.03	39.11	
6553	19.848	15.3	15.7	32	19	10.41						
6566	20.553	19.6	11.3	50	10	39.15	—	17.78	+2.09	0	39.09	
6583	28.189	16.1	14.9	56	39	44.39						
6637	12.911	17.9	13.1	26	2	23.96	—6	25.39	+1.59	—.12	40.26	
6690	21.076	17.2	13.9	27	42	56.77						
6748	15.950	16.7	14.7	54	42	2.89	+2	9.30	+1.40	+.03	40.56	
6830	18.040	15.4	15.6	47	37	49.94						
6851	24.079	18.1	13.0	34	46	23.87	+2	32.34	+1.30	+.04	40.55	
6933	26.602	15.7	15.6	20	34	3.92						There is an error of 5 revolutions in one or other micrometer reading.
6970	17.579	16.8	14.3	61	43	26.51	+5	53.73	+ .69	+.08	39.72	
7022	14.705	15.1	16.1	39	52	55.45						
7100	27.932	19.4	12.0	42	47	34.45	—5	33.65	+1.70	—.09	42.91	
7273	27.534	15.9	15.8	44	28	23.38						
7320	14.895	16.5	14.9	38	11	36.06	—5	18.82	+ .45	—.09	41.26	
	18.606	16.0	15.4	59	47	16.99						Fed. 3689.
7361	25.799	13.8	18.0	22	36	2.11	+3	1.44	— .95	+.06	40.10	

Latitude of Wilkes Barre—Continued.

B. A. C.	Micrometer.	Level. N.	Level. S.	Declination.			Corrections. Micrometer.		Corrections. Level.	Corrections. Ref.	Latitude.			Remarks.
				°	′	″	′	″	″	″	°	′	″	
7462	15.900	15.6	16.1	36	36	21.17								
7480	25.790	15.7	16.1	46	1	18.85	—4	9.48	— .24	—.07	41	14	40.22	
7521	16.963	17.1	14.7	39	53	6.55								
7544	26.635	13.8	18.0	42	44	22.54	—4	3.97	— .48	—.07			40.03	
7627	20.047	17.3	14.8	25	22	15.83								
7668	18.354	14.2	17.9	57	5	38.58	+	42.71	— .32	+.01			39.61	
7706	24.887	16.4	15.7	24	46	13.45								
7749	17.812	13.1	18.8	57	37	11.57	+2	58.47	—1.33	+.06			39.71	
7824	25.697	13 9	18.0	50	39	22.99								
7843	15.973	17.3	14.8	31	58	11.04	—4	5.29	— .42	—.07			41.24	
7932	19.601	18.3	14.0	41	12	1.25								
7962	22.401	12.9	19.3	41	19	43.82	—1	10.63	— .56	—.02			41.33	August 12.
8024	26.733	13.2	19.0	56	28	13.93								
8079	13.049	17.9	14.7	26	12	37.59	—5	45.18	— .69	—.10			39.99	
8118	19.081	18.5	14.0	41	7	43.75								
8128	24.130	11.0	21.6	41	25	53.70	—2	7.36	—1.62	—.03			39.72	
8177	12.555	14.2	18.2	5	43	56.10								
8238	27.832	17.3	15.2	76	58	15.45	—6	25.36	— .50	—.16			39.76	
8293	22.304	18.0	14.9	8	39	37.49								
8314	16.708	14.8	18.1	73	45	2.75	+2	21.16	— .05	+.05			41.38	

16	28.998	18.1	14.9	45	24	50.37						
67	12.017	14.9	18.2	37	18	48.63	—7	8.35	— .02	—.12	41.01	
109	25.771	17.1	16.1	29	6	0.89						
153	15.485	15.4	17.9	53	14	41.04	+4	19.46	— .40	+.08	40.11	
255	20.935	17.0	16.1	59	43	13.37						
264	20.177	16.9	16.2	22	46	47.09	—	19.12	+ .42	—.01	41.52	
	27.457	19.0	14 0	67	8	45.23						L.L. 1985.
370	15.656	13.0	20.0	15	30	30.76	—4	57.68	— .53	—.10	39.69	
412	11.608	16.1	16.7	67	30	34.04						
453	28.944	16.7	16.1	14	44	13.78	+7	17.30	0	+.15	41.36	

Mean of 47 determinations 41° 14′ 40″.48±11.

Latitude of Pottsville.

B. A. C.	Micrometer.	Level.		Declination.	Corrections.			Latitude.	Remarks.
		N.	S.		Micrometer.	Level.	Ref.		
				° ′ ″	′ ″	″	″	° ′ ″	
438	15.789	14.8	16.0	69 39 10.62					
488	28.700	17.1	13.8	11 32 17.56	+5 25.68	+ .56	+.12	40 41 10.45	August 20.
515	31.045	18.8	12.0	59 57 8.09					
556	12.051	4.3	26.5	21 41 18.73	—7 59.12	—4.08	—.15	10.06	
611	25.863	16.1	15.0	63 48 56.79					
632	16.657	15.0	16.0	17 41 7.93	—3 52.22	+ .03	—.08	10.09	
656	24.891	15.4	15.7	34 25 36.89					
706	16.843	15.7	15.9	46 49 54.52	+3 23.01	— .13	+.06	8.64	
744	21.957	15.6	16.0	66 51 59.50					
780	21.496	15.5	16.1	14 30 41.05	— 11.63	— .26	0	8.38	
816	20.669	14.8	17.0	54 35 52.50					
872	20.796	16.9	14.9	26 46 19.68	+ 3.20	— .05	0	9.24	
897	20.707	14.7	17.1	46 40 53.82					
915	19.490	17.0	14.8	34 42 25.65	— 30.70	— .05	—.01	8.98	
950	27.454	18.8	13.1	3 53 15.47					
979	13.905	12.9	19.0	77 17 37.32	+5 41.77	— .11	+.15	8.21	
7561	29.504	12.1	13.1	9 20 12.60					
7597	11.249	6.1	18.8	71 46 49.19	+7 40.48	—3.63	+.18	7.93	August 21.

7627	19.215	14.2	11.0	25	22	20.60						
7643	23.015	5.0	20.3	56	3	15.78	—1	35.76	—3.21	—.03	9.19	
7931	15.942	14.8	11.0	38	50	53.83						
7972	27.564	12.1	13.5	42	41	9.48	—4	53.16	+ .66	—.08	9.08	
8052	22.251	12.1	13.1	24	49	57.75						
8083	20.655	10.1	15.6	56	30	58.99	+	40.26	—1.72	+.01	6.92	
8138	24.732	13.9	12.0	61	33	59.96						
8147	16.992	14.9	11.0	19	54	48.72	—3	15.24	+1.54	—.06	10.58	
8195	28.942	13.5	12.0	38	35	18.14						
8229	16.915	10.1	15.6	42	36	53.13	+5	3.38	—1.06	+.08	8.04	
8272	22.601	15.0	11.0	7	35	32.44						
8314	20.610	9.3	16.4	73	45	5.84	+	50.22	— .82	+.02	8.56	
8330	29.010	13.0	12.9	55	5	49.68						
8350	15.926	15.0	11.0	26	27	28.87	—5	30.04	+1.09	—.10	10.23	
8373	9.980	14.8	11.4	63	32	15.18						
8	29.765	11.3	14.7	17	33	24.72	+8	19.08	0	+.16	9.19	
52	12.000	12.7	13.1	38	1	33.11						
78	30.807	11.0	15.0	43	36	34.37	—7	54.41	— .11	—.13	9.09	
99	28.895	17.8	8.3	18	51	43.53						
126	12.356	7.1	18.7	62	16	41.25	+6	57.20	— .56	+.13	9.16	
166	30.485*	15.0	11.0	30	12	52.75						
235	13.119	10.2	16.0	50	55	37.60	+6	52.83	— .48	+.13	7.66	August 21.
254	18.476	11.0	15.2	58	32	27.01						
264	22.101	17.8	8.5	22	46	49.08	+1	31.44	+1.35	+.03	10.87	

* There is an error of one revolution in one of these readings.

Latitude of Pottsville—Continued.

B. A. C.	Micrometer.	Level.		Declination.	Corrections.			Latitude.	Remarks.
		N.	S.		Micrometer.	Level.	Ref.		
				° ′ ″	′ ″	″	″	° ′ ″	
305	18.940	15.1	11.0	14 18 41.73					
	25.120	9.4	16.8	67 8 47.77	—2 35.89	— .87	—.05	40 41 7.94	L. L. 1985.
438	14.273	12.8	13.8	69 39 10.90					
488	27.156	13.6	13.0	11 32 17.72	+5 24.97	— .11	+.12	9.29	
515	32.255	13.6	13.0	59 57 8.35					
556	13.112	12.9	13.8	21 41 18.92	—8 2.88	— .08	—.15	10.53	
611	25.200	14.9	12.2	63 48 57.03					
632	15.980	11.0	16.1	17 41 8.09	—3 52.57	— .64	—.08	9.27	
656	24.573	13.6	13.3	34 25 37.09					
706	16.499	14.3	12.9	46 49 54.72	+3 23.67	+ .45	+.06	10.08	
7984	18.772	16.0	15.7	39 44 54.75					
8023	23.798	17.5	14.1	41 41 32.75	—2 6.78	+ .98	—.03	7.92	August 22.
8052	21.561	15.1	16.5	24 49 58.06					
8083	20.030	19.5	12.1	56 30 59.46	+ 38.62	+1.59	+.01	8.98	
8138	23.457	14.7	17.3	61 34 0.31					
8147	15.694	21.0	11.0	19 54 48.72	—3 15.82	+1.96	—.06	10.60	
8195	27.775	16.1	15.7	38 35 18.37					
8229	15.719	16.1	15.7	42 36 53.44	+5 4.11	+ .24	+.08	10.34	
8272	22.189	17.1	14.9	7 35 32.59					
8314	20.243	14.1	17.5	73 45 6.20	+ 49.09	— .32	+.02	8.19	

8330 8350	28.268 15.232	19.8 11.2	12.1 20.8	55 26	5 27	50.00 29.10	—5	28.83	— .50	—.10	10.12	
8373 8	11.356 31.115	14.8 16.7	17.2 15.2	63 17	32 33	15.65 24.95	+8	18.42	— .24	+.16	8.64	
52 78	11.913 30.750	13.5 18.2	18.2 13.5	38 43	1 36	33.39 34.66	—7	55.16	0	—.13	8.74	
99 126	29.114 12.626	17.1 14.7	14.9 17.2	18 62	51 16	43.73 41.58	+6	55.91	— .08	+.13	8.62	
166 235	29.395 13.047	17.1 14.9	14.9 17.2	30 50	12 55	53.00 37.89	+6	52.38	— .03	+.13	7.93	
305	18.690 24.929	17.2 14.2	14.8 17.8	14 67	18 8	41.91 48.29	—2	37.38	— .32	—.05	7.35	LL. 1985.
361 360	24.316 16.979	12.1 20.1	20.0 12.1	—7 88	24 40	27.65 31.50	+3	5.08	+ .03	+.11	7.14	
438 488	14.615 27.453	15.7 17.5	16.7 14.9	69 11	39 32	11.18 17.87	+5	23.84	+ .42	+.12	8.89	August 22.
515 556	30.511 11.276	16.8 17.1	15.8 15.2	59 21	57 41	8.61 19.10	—8	5.20	+ .77	—.15	9.43	
611 632	26.029 16.789	16.7 18.0	16.0 14.9	63 17	48 41	57.27 8.25	—3	53.08	+1.01	—.08	10.61	
656 706	26.317 18.306	18.0 16.1	14.8 16.7	34 46	25 49	37.29 54.93	+3	22.08	+ .69	+.06	8.94	
744 780	21.554 21.039	15.1 19.2	17.9 13.6	66 14	51 30	59.90 41.52	—	12.99	+ .74	0	8.46	
816 872	21.298 21.394	16.6 17.0	16.5 16.1	54 26	35 46	52.87 20.00	+	2.42	+ .26	0	9.11	

Latitude of Pottsville—Continued.

B. A. C.	Micrometer.	Level. N.	Level. S.	Declination.	Corrections. Micrometer.	Corrections. Level.	Corrections. Ref.	Latitude.	Remarks.
				° ′ ″	′ ″	″	″	° ′ ″	
897 915	22.024 20.763	16.1 18.7	17.1 14.9	46 40 53.96 34 42 25.97	— 31.81	+ .74	—.01	40 41 8.89	
950 979	27.553 14.065	17.3 18.0	16.0 15.5	3 53 15.70 77 17 37.58	+5 40.23	+1.01	+.15	8.03	
7934 8023	19.384 24.315	15.0 16.0	16.1 15.9	39 44 55.05 41 41 33.07	—2 4.38	— .26	—.03	9.36	August 23.
8052 8083	22.216 20.615	19.1 9.4	13.1 22.9	24 49 58.23 56 30 59.69	+ 40.37	—1 99	+.01	7.35	
8138 8147	24.413 16.707	15.4 17.1	17.3 15.6	61 34 0.67 19 54 49.15	—3 14.38	— .11	—.06	10.36	
8195 8229	28.590 16.535	18.1 14.0	14.7 18.6	38 35 18.60 42 36 53.74	+5 4.09	— .32	+.08	10.02	
8272 8314	23.210 21.245	14.9 18.0	18.1 15.1	7 35 32.75 73 45 6.56	+ 49.57	— .08	+.02	9.17	
8330 8350	28.411 15.314	14.7 18.9	18.9 14.9	55 5 50.33 26 27 29.34	—5 30.37	— .05	—.10	9.32	
8373 8	10.915 30.721	14.8 18.9	18.9 14.8	63 32 16.12 17 33 25.19	+8 19.61	0	+.16	10.43	
52 78	11.223 30.069	15.0 17.1	18.2 15.1	38 1 33.67 43 36 34.95	—7 55.39	—.32	—.13	8.47	

99	29.095	19.1	14.7	18	51	43.93						
126	12.574	14.8	19.1	62	16	41.90	—6	56.74	— .03	+.13	9.87	
166	30.449	17.8	16.1	30	12	53.24						
235	14.111	19.4	14.8	50	55	38.17	+6	52.13	+1.67	+.13	9.64	
254	19.463	17.8	16.6	58	32	27.62						
264	23.023	19.7	14.7	22	46	49.40	+1	29.80	+1.64	+.03	9.98	
305	17.775	18.8	15.6	14	18	42.08						August 23.
	24.042	16.5	17.8	67	8	48.80	—2	38 09	+ .50	—.05	7.80	L.L. 1985.
361	24.035	15.1	19.0	—7	24	27.55						
360	16.766	19.3	15.0	88	40	31.80	+3	3.36	+ .11	+.11	5.71	Rejected.
438	13.844	20.9	13.8	69	39	11.46						
488	26.689	14.0	20.8	11	32	18.03	+5	24.02	+ .08	+.12	8.96	
515	31.585	19.0	15.2	59	57	8.87						
556	12.307	18.7	16.1	21	41	19.28	—8	6.29	+1.70	—.15	9.34	
611	25.861	19.5	15.4	63	48	57.51						
632	16.572	19.0	16.1	17	41	8.42	—3	54.32	+1.86	—.08	10.43	
656	25.731	19.8	15.6	34	25	37.49						
706	17.741	19.5	16.7	46	49	55.14	+3	21.55	+1.86	+.06	9.79	
744	21.370	15.6	20.0	66	52	0.10						
780	20 845	24.9	11.0	14	30	41.66	—	13.24	+2.52	0	10.16	

Mean of 63 determinations 40° 41′ 9″.13±.08.

We therefore have the following as the geographical position of the point occupied by the Transit instrument at Wilkes Barre:

Latitude $41^\circ\ 14'\ 40''.48$.

Longitude $\left\{\begin{array}{l} 0^h\ \ 4^m\ 40^s.24 \text{ (time)} \\ 1^\circ\ 10'\ \ 3''.6^* \text{ (arc)} \end{array}\right\}$ East of Washington.

For the point occupied by the Transit instrument at Pottsville we have:

Latitude $40^\circ\ 41'\ 9''.13$.

Longitude $\left\{\begin{array}{l} 0^h\ \ 3^m\ 24^s.71 \text{ (time)} \\ 0^\circ\ 51'\ 10''.65 \text{ (arc)} \end{array}\right\}$ East of Washington.

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* See foot note page 274.

FIRST REPORT OF THE PROGRESS

OF THE

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA,

IN THE

ANTHRACITE DISTRICT.

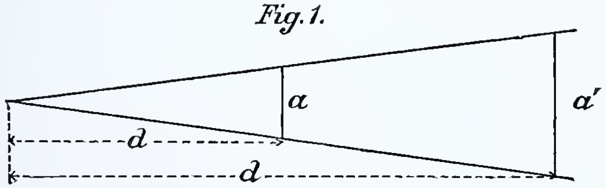
APPENDIX B.

THE THEORY OF STADIA MEASUREMENTS, ACCOMPANIED BY TABLES OF HORIZONTAL DISTANCES AND DIFFERENCES OF LEVEL FOR THE REDUCTION OF STADIA FIELD OBSERVATIONS,*

BY ARTHUR WINSLOW.

The fundamental principle upon which stadia measurements are based, is the geometrical one that the lengths of parallel lines subtending an angle are proportional to their distances from its apex. Thus if, in Fig. 1, a represents the

Fig. 1.



length of a line subtending an angle at a distance d from its apex, and a′ the length of a line, parallel to and twice the length of a, subtending the same angle at a distance d′ from its apex, then will d′ equal 2d.

* Most of the field surveys, which are being made by the Geological Corps, in the Anthracite District are based upon stadia measurements. This method of measuring has never been generally used by the mining engineers throughout the region. In some localities its accuracy is questioned, and the

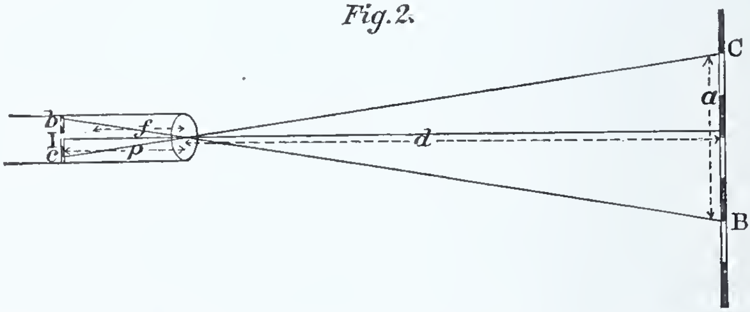
This is, in a general way, the underlying principle of stadia work; the nature of the instruments used, however, introduces several modifications, and these will be best understood by a consideration of the conditions under which such measurements are generally made.

There are placed, in the telescopes of most instruments, fitted for stadia work, either two horizontal wires (usually adjustable) or a glass with two etched horizontal lines at the position of the cross wires, and equidistant from the center wire.

A self-reading stadia rod is further provided, graduated according to the units of measurement used.

In a horizontal sight with such a telescope and rod, the positions of the stadia wires are projected upon the rod and intercept a distance which in Fig. 2 is represented by a.

Fig. 2.



In point of fact there is formed, at the position of the stadia wires, a small conjugate image of the rod which the wires intersect at points b and c, which are respectively the foci of the points B and C on the rod. If, for simplicity sake, the object glass be considered a simple bi-convex lens, then, by a principle of optics, the rays from any point of an object converge to a focus at such a position that a straight line, called a secondary axis, connecting the point

strongest prejudice exists against its adoption. Except in special triangulation surveys, or those based upon measurements made with level measuring rods or long steel tapes, I believe the most accurate work is based upon stadia measurements. The accompanying discussion, by Mr. Winslow, of the theory of stadia work, with tables for the reduction of stadia observations, has been published as an appendix to my report, for the information and use of engineers and surveyors in the Anthracite Coal Fields.

CHAS. A. ASHBURNER,
Geologist in Charge.

with its image, passes through the *center* of the lens. This point of intersection of the secondary axes is called the optical center. Hence, it follows that lines such as c C and b B, in Fig. 2, drawn from the stadia wires through the center of the object glass will intersect the rod at points corresponding to those which the wires cut on the *image* of the rod. From this follows the proportion:

$$\frac{d}{p}=\frac{a}{I} \therefore d=\frac{p}{I}a. \quad (1)$$

Where: d = the distance of the rod from the center of the objective;

p = the distance of the stadia wires from the center of the objective;

a = the distance intercepted on the rod by the stadia wires;

I = the distance of the stadia wires apart.

If p remained the same for all lengths of sight, then $\frac{p}{I}$ could be made a desirable constant and d would be directly proportional to a. Unfortunately, however, for the simplicity of such measurements, p (the focal length) varies with the length of the sight, increasing as the distance diminishes and *vice versa*. Thus the proportionality between d and a is variable.

The object, then, is to determine exactly what function a is of d and to express the relation in some convenient formula.

The general formula for bi-convex lenses is:

$$\frac{1}{p}+\frac{1}{p'}=\frac{1}{f} \quad (2)$$

f is the *principal* focal length of the lens, and p and p′ are the focal distances of image and object and are *approximately* the same as p and d, respectively, in equation (1):

therefore, $\frac{1}{p}+\frac{1}{d}=\frac{1}{f}$, approximately.

and $\frac{d}{p}=\frac{d}{f}-1$

From (1), $\frac{d}{p}=\frac{a}{I}$

$$\therefore \frac{a}{I}=\frac{d}{f}-1$$

whence, $d=\frac{f}{I}a+f$ . . . . (3)

In this formula, it will be noticed that, as f and I remain constant for sights of all lengths, the factor by which a is to be multiplied is a constant, and that d is thus equal to a constant times the length of a, plus f. This formula would seem, then, to express the relation desired and it is generally considered as the fundamental one for stadia measurements. As above stated, however, the equation $\frac{1}{p}+\frac{1}{d}=\frac{1}{f}$ is only *approximately* true and the conjunction of this formula with (2) being, therefore, not rigidly admissible, equation (3) does not express the exact relation.* The equation expressing the true relation, though differing from (3) in value, agrees with it in form and also, in that the expression corresponding to $\frac{f}{I}$ is a constant and that the amount to be added remains, practically, f. The constant corresponding to $\frac{f}{I}$ may be called k† and thus the distance of the rod from the objective of the telescope is seen to be equal to a constant times the reading on the rod, plus the principal focal length of the objective. To obtain the exact distance to the *center* of the instrument, it is further necessary to add the distance of the objective from that center, to f; which sum may be called c. The final expression for the distance, with a horizontal sight, is then

$d=ka+c$ . . . . (4)

The necessity of adding c is somewhat of an incumbrance. In the stadia work of the U. S. Government surveys an approximate method is adopted in which the total distance is read directly from the rod. For this method the rod is

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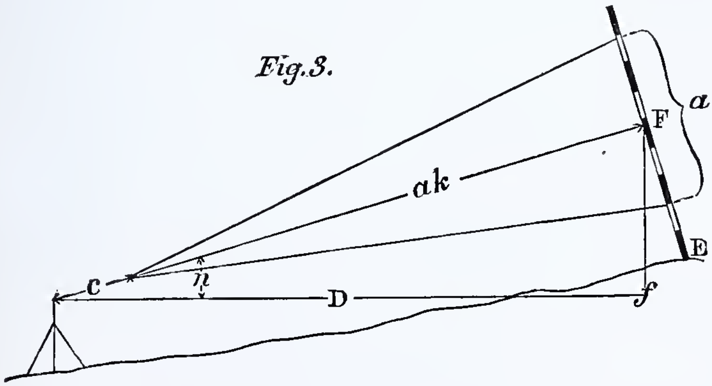
* This is demonstrated on pages 334, 335, &c.

† k is dependent upon I and can, therefore, be made a convenient value in any instrument fitted with adjustable stadia wires. It is generally made equal to 100, so that a reading on the rod of 1′ corresponds to a distance of 100′ + f.

arbitrarily graduated, so that, at the distance of an average sight, the same number of units of the graduation are intercepted, between the stadia wires on the rod, as units of length are contained in the distance. For any other distance, however, this proportionality does not remain the same; for, according to the preceding demonstration, the reading on the rod is proportional to its distance, not from the center of the instrument, but from a point at a distance "c" in front of that center; so that, when the rod is moved from the position where the reading expresses the *exact* distance, to a point, say half that distance from the instrument center, the reading expresses a distance *less* than half; and, at a point double that distance from the instrument center the distance expressed by the reading is *more* than twice the distance. The error for all distances less than the average being minus, and for greater distances plus. The method is, however, a close approximation and excellent results are obtained by its use.

Another method of getting rid of the necessity of adding the constant was devised by Mr. Porro, a Piedmontese, who constructed an instrument in which there was such a combination of lenses in the objective, that the readings on the rod, for all lengths of sight, were exactly proportional to the distances.* The instrument was, however, bulky and difficult to construct and never came into extensive use.

Fig. 3.



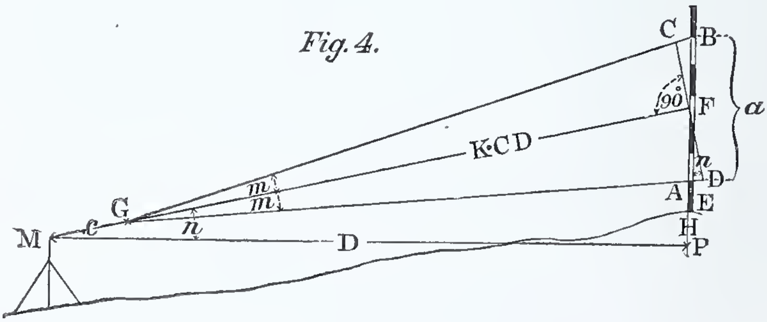
* A notice of this instrument will be found in an article by Mr. Benjamin Smith Lyman, entitled "Telescopic Measurements in Surveying," in Jour. Franklin Inst., May and June, 1868, and a fuller description is contained in the Annales des Mines, Vol. XVI, Fourth Series.

For stadia measurements with inclined sights there are two modes of procedure. One, is to hold the rod at right angles to the line of sight; the other, to hold it vertical. With the first method it will be seen, by reference to Fig. 3, that the distance read is not to the foot of the rod, E, but to a point f, vertically under the point F, cut by the center wire. A correction has, therefore, to be made for this. An objection to this method is the difficulty of holding the rod at the same time in a vertical plane and inclined at a definite angle. Further, as the rod changes its inclination with each new position of the transit, the vertical angles of back and foresight are not measured from the same point.

The method usually adopted is the second one where the rod is always held *vertical*. Here, owing to the oblique view of the rod, it is evident that the space intercepted by the wires on the rod varies, not only with the distance, but also, with the angle of inclination of the sight. Hence, in order to obtain the true distance from station to station and also its vertical and horizontal components, a correction must be made for this oblique view of the rod. In Fig. 4,

AB=a=the reading on the rod;
MF=d=the inclined distance=c+GF=c+k.CD;
MP=D=the horizontal distance=d cos n
FP=Q=the vertical distance=D tan n
n=the vertical angle;
AGB=2m

Fig. 4.



It is first required to express d in terms of a, n and m.

From the proportionality existing between the sides of a triangle and the sines of the opposite angles,

$$\frac{AF}{GF}=\frac{\sin m}{\sin [90^\circ+(n-m)]}$$

$$\text{or, } AF=GF \sin m \frac{1}{\cos (n-m)};$$

$$\text{and } \frac{BF}{GF}=\frac{\sin m}{\sin [90^\circ-(n+m)]}$$

$$\text{or, } BF=GF \sin m \frac{1}{\cos (n+m)};$$

$$\therefore AF+BF=GF \sin m \left[\frac{1}{\cos (n-m)}+\frac{1}{\cos (n+m)}\right]$$

$$AF+BF=a, \text{ and } GF=\frac{CD}{2}\frac{1}{\tan m}=\frac{CD}{2}\frac{\cos m}{\sin m}$$

By substituting and reducing to a common denominator,

$$a=\frac{CD}{2}\frac{\cos m [\cos (n+m)+\cos (n-m)]}{\cos (n+m) \cos (n-m)}$$

Reducing this according to trigonometrical formulæ,

$$CD=a\frac{\cos^2 n \cos^2 m-\sin^2 n \sin^2 m}{\cos n \cos^2 m}$$

as $d=MF=c+k.CD$,

$$\therefore d=c+k\,a\,\frac{\cos^2 n \cos^2 m-\sin^2 n \sin^2 m}{\cos n \cos m^2}$$

The horizontal distance, $D = d \cos n$.

$$\therefore D=c \cos n+ka \cos^2 n-k\,a \sin^2 n \tan^2 m.$$

"The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for 1500′, $n = 45^\circ$ and $k = 100$, it is but 0.07′.) Therefore, the final formula for distances, with a stadia rod held vertically, and with wires equidistant from the center wire, is the following:"

$$D = c \cos n + a\,k \cos^2 n \quad . \; . \; . \; . \; . \; . \; . \; (5)$$

The vertical distance Q, is easily obtained from the relation: $Q=D \tan n$.

$$\therefore Q=c \sin n+a\,k \cos n \sin n$$

$$\text{or } Q=c \sin n+a\,k\frac{\sin 2n}{2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; (6)^*$$

* The above demonstration is substantially that given by Mr. George J. Specht, in an article on Topographical Surveying in Van Nostrand's Engineering Magazine for February, 1880, though enlarged and corrected.

With the aid of formulæ (5) and (6,) the horizontal and vertical distances can be immediately calculated when the reading from a *vertical* rod, and the angle of elevation, of any sight, are given. I have calculated from these formulæ the stadia reduction tables (pages 342, 343 and 344). The values of $a\ k\ \cos^2 n$ and $a\ k\ \frac{\sin 2n}{2}$ were separately calculated for each two minutes up to 30 degrees of elevation; but, as the value of c sin n and c cos n have quite an inappreciable variation for 1 degree, it was thought sufficient to determine these values only for each degree. As c varies with different instruments these last two expressions were calculated for three different values of c, thus furnishing a ratio from which values of c sin n and c cos n can be easily determined for an instrument having any constant (c.)

Similar tables have been computed by J. A. Ockerson and Jared Teeple, of the U. S. Lake Survey. Their use is, however, limited, from the fact that the meter is the unit of horizontal measurement while the elevations are in feet. The bulk of the tables furnish differences of level for stadia readings up to 400 meters, but only up to 10° of elevation. Supplementary tables give the elevations up to 30° for a distance of one meter. For obtaining horizontal distances reference has to be made to *another* table, which is some what an objectionable feature, and a multiplication *and* a subtraction has to be made in order to obtain the result. Last, but not least, these tables are, apparently, only accurate when used with an instrument whose constant is 0.43 meters.

The many advantages of stadia measurements in surveying need not be dwelt upon here, both because attention has been repeatedly called to them, and because they are self-evident to every engineer. Neither will it be within the compass of this article to describe the various forms of rods and instruments, or the conventionalities of stadia work.

A few precautions, necessary for accurate work, should, however, be emphasized. First, as regards the special adjustments: care should be taken that in setting the stadia wires* allowance be made for the instrument constant, and that the wires are so set that the reading, at any distance, is less than the true distance by the amount of this constant.†

For accurate stadia work it is better to take the reading for both distances and elevations only at alternate stations and then to take them from both back and fore sights, in such a manner that the vertical angle is always read from the same position on each rod, which should be the average height of the telescope at the different stations. If it be desired to have the absolute elevation of the ground under the instrument, the height of the telescope at each station will have to be measured by the rod, and the difference between this measurement and the average height used in sighting to the rod either added or subtracted as the case may be. This difference will ordinarily be so small, that in a great deal of stadia work no reduction will be necessary. In sighting to the rod for the angle of depression or elevation, the center horizontal wire must always be used. By this means an exactly continuous line is measured. Cases will, of course, occur where this method will be impracticable and then the mode of procedure must be left to the judgment of the surveyor.

For theoretical exactness it is necessary that the stadia wires should be equidistant from the center horizontal wire, for, if this be not the case, the distance read is for an angle of elevation differing from the true one by an amount proportional to the displacement of the wires.

With reasonable care a high degree of accuracy can be

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*This applies to an instrument with movable stadia wires, and not one with etched lines on glass. In the latter case the graduation of the rod is the adjustable portion. It has been claimed as an advantage for etched lines on glass, that they are not affected by variations of temperature while the distance between stadia wires is. A series of tests which I made with one of Heller & Brightly's transits, to determine this point, showed no appreciable alteration in the space between the wires, as measured on a rod 500 feet distant, with a range of temperature between that produced in the instrument by the sun of a hot summer's day and that produced by enveloping the telescope in a bag of ice.

†This is assuming the measurements to be made by the ordinary method, and not by the approximate one of the U. S Engineers.

attained in stadia measurements. The common errors of stadia reading are unlike the common errors of chaining, the gross ones (such as making a difference of a whole hundred feet) being, in general, the only important ones, and these are readily checked by double readings. To facilitate the substraction of the reading of one cross hair from that of another, one should be put upon an even foot mark, and in the check reading the other one.

A general measure of the efficiency of stadia measurements is furnished in the professional papers of the Corps of Engineers, U. S. A., for 1882, on the Primary Triangulation of the Lake Survey, where it is stated that, in computing coördinates of stadia work for 1875, the average amount of discrepancy in 141 lines, varying between 965 and 6,648 meters (mean 2,450 meters,) when compared with lines determined by triangulation or chaining, was found to be 1 in 649. The maximum limit of error is put at 1 in 300.

Mr. Benjamin Smith Lyman, who has made extensive use of stadia work both in this country and Japan, considers it decidedly more accurate than ordinary good chaining, if the gross errors be carefully avoided.

As stated in the preceding discussion, the generally accepted formula expressing the relation between the distance in a horizontal sight, the reading on the rod, the distance of the stadia wires apart, and the focal length of the objective is

$$d = \frac{f}{I} a + f \quad \ldots\ldots\ldots\ldots \quad (3)$$

where d, a, I and f represent these factors respectively.

This formula is derived from the conjunction of the two equations:

$$d = \frac{p}{I} a ; \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\text{and } \frac{1}{p} + \frac{1}{p'} = \frac{1}{f} ; \quad \ldots\ldots\ldots\ldots \quad (2)$$

p and p′ in (2,) being considered as equal to p and d in (1) which, it will be remembered, are the distances from the *center* of the objective to the image and object respectively. But the general formula for lenses, (2), is derived on the supposition that p and p′ are measured from the *exterior faces* of the lens, and therefore p and d in (1) are each greater, by half the thickness of the lens, than p and p′ in (2). Further, this formula is derived on the supposition that the object glass of the telescope is a simple, biconvex lens, whereas, in fact, it is a compound lens composed of a plano concave and a biconvex lens. Now, though these points may seem insignificant in themselves, they may influence the final result, as a difference of only 1 in the denominator of such a fraction as $\frac{1,000,000}{2}$ may alter the result by as much as 500,000. Considerable thought and time has, therefore, been given to the consideration of the effect of these corrections, and, as a result, it was found that the formula (3) does not express the true relation even within practical limits; and that if it were attempted to calculate the distance, d, by this formula, when the factors f, p and a were given, a result would be obtained which would differ considerably from the real distance. The inaccuracy lies in the expression $\frac{f}{I}$. The one to be substituted for it is, however, like it, a constant for each instrument; and, as we determine the value of this constant by actual trial and not from a knowledge of the values of f and I, the correction to be made will not affect the practice.

Considering first the case of a telescope with a simple, biconvex lens, the optical center, being, here, in the center of the lens, d and p, in equation (1), as before stated, are measured from the center of the lens, while, in equation (2), p and p′ are measured from the exterior faces. If the thickness of the lens be taken as 2x, then

p in equation (1)=p in equation (2), minus x; and
p′ " " =d " " " x.

Therefore, while (1) remains $d=\frac{p}{I}a$, or $p=\frac{I}{a}d$ . . . . (1a),

by substitution, (2), becomes, $\frac{1}{p-x}+\frac{1}{d-x}=\frac{1}{f}$ . . . (2a).

Substituting $d\frac{I}{a}$ for p in (2a)

$$\frac{1}{d\frac{I}{a}-x}+\frac{1}{d-x}=\frac{1}{f}$$

$$\therefore d-x+d\frac{I}{a}-x=\frac{1}{f}\left(d-x\right)\left(d\frac{I}{a}-x.\right)$$

$$=\frac{1}{f}d^2\frac{I}{a}-\frac{1}{f}d\frac{I}{a}x-\frac{1}{f}dx+\frac{1}{f}x^2$$

whence, $$-2x-\frac{1}{f}x^2=\frac{1}{f}d^2\frac{I}{a}-d\frac{1}{f}x\left(\frac{I}{a}+1\right)-d\left(\frac{I}{a}+1\right)$$

or $$=\frac{1}{f}d^2\frac{I}{a}-d\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right].$$

Multiplying both sides by $\frac{I}{a}\frac{1}{f}$.

$$-\frac{I}{a}\frac{1}{f}\left(2x+\frac{1}{f}x^2\right)=\frac{1}{f^2}d^2\frac{I^2}{a^2}-\frac{I}{a}\frac{1}{f}d\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]$$

Adding to both sides $\frac{\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]}{2}$ squared,

$$\frac{\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]^2}{4}-\frac{I}{a}\frac{1}{f}\left(2x+\frac{1}{f}x^2\right)=\left(d\frac{1}{f}\frac{I}{a}\right)^2-d\frac{1}{f}\frac{I}{a}\times$$

$$\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]+\frac{\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]^2}{4}.$$

Extracting the square root of both terms,

$$\sqrt{\frac{\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]^2}{4}-\frac{1}{f}\frac{I}{a}\left(2x+\frac{1}{f}x^2\right)}=d\frac{1}{f}\frac{I}{a}$$

$$-\frac{\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)}{2}$$

$$\therefore\left[\sqrt{\frac{\left[\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)\right]^2}{4}-\frac{1}{f}\frac{I}{a}\left(2x+\frac{1}{f}x^2\right)}\right.$$

$$\left.+\frac{\left(\frac{I}{a}+1\right)\left(\frac{1}{f}x+1\right)}{2}\right]\frac{af}{I}=d$$

or, $$d=\frac{(I+a)\ (x+f)}{2I}+\sqrt{\frac{[(I+a)(x+f)]^2}{4I^2}-\frac{a}{I}(x^2+2xf)}\quad .\ (3a)$$

This is the *exact* formula corresponding to (3), for biconvex lenses. This can, however, be considerably reduced without materially affecting its value. With a telescope of the dimensions of that of an ordinary engineer's transit, the term $\frac{a}{I}(x^2+2xf)$ diminishes the result by about $\frac{1}{3}$ of an inch and, therefore, may be neglected. Formula (3a), then becomes:

$$d=\frac{(I+a)(x+f)}{I}$$

$$=\frac{Ix+If+ax+af}{I}$$

$$=a\frac{x+f}{I}+f+x$$

The addition of x (half the thickness of the object glass) would be inappreciable in the length of any ordinary sight, and may be omitted. The final expression becomes, then:

$$d=\frac{x+f}{I}a+f \quad . \quad . \quad . \quad . \quad (3b)$$

This formula, it will be observed, differs from (3) in that the reading on the rod, (a), is multiplied by $x+f$ instead of f. The numerical difference between the results is seen in the following examples:

Consider first the case with a one-foot reading on the rod, and let $x=.18''$, $f=9.00''$, and $I=.08''$.*

Formula (3) becomes, then:

$$d=\frac{9.00''}{.08''}12.00''+9.00''=1359''=113.25';$$

Formula (3b) becomes:

$$d=\frac{.18''+9.00''}{.08''}12.00''+9.00''=1386=115.50'$$

Difference = 2.25'

When the reading on the rod is 5 feet (or 60″) then, (3) becomes:

$$d=\frac{9.00''}{.08''}60.00''+9.00''=563.25';$$

and (3b) becomes:

$$d=\frac{.18''+9.00''}{.08''}60.00''+9.00''=574.50'$$

Difference = 11.25'†

*These are very closely the dimensions in Heller & Brightly's large Surveyor's Transit 5-inch needle, as kindly furnished me by Mr. Heller. The magnifying power of the telescope was 28 diameters.

† As the difference is evidently proportional to the length of sight, with a 1000′ sight it would amount to 22.5′, etc.

The above demonstration shows, then, that, with a simple biconvex object glass, the usually accepted formula expressing the relation between the distance, the reading on the rod, the distance of the stadia wires apart, and the focal length of the objective, is not accurate even within the limits of accuracy of such measurements. With the usual combination of lenses in objectives this error would still remain. The derivation of a formula similar to (3b), for such lenses, would, however, be extremely difficult and would only hold for the special lens in question. For, with such a combination of lenses, the optical center would no longer remain in the center of the lens, but would vary its position according to the relative thicknesses of the two glasses, their radii of curvature and their indices of refraction ; and, after its position had been determined by abstruse calculation and refined experiment, its distance from the two exterior faces of the compound lens would be expressed by *two different* values (x and x') instead of two equal values (x); and this would very much complicate further calculation.

It was seen that, in the newly deduced formula, for biconvex objectives, like that heretofore accepted, the factor by which the reading on the rod is multiplied is a constant for each instrument and that the practical method of adjusting the instrument remains the same. The question now arises, does this remain the case with a compound objective?

In view of the difficulty of demonstrating this mathematically it was decided to make a practical test of this point with a carefully adjusted instrument. A distance of 500 feet was first measured off on a level stretch of ground, and each 50 foot point accurately located. From one end of this line three successive series of stadia readings* were then taken from the first 50 foot and each succeeding 100 foot mark. The following table contains the results :

* The readings were taken from two targets set so that the sight should be horizontal and thus also preventing any personal error or prejudice from affecting the reading.

Distances.	Spaces intercepted on the rod.			
	1st Series.	2d Series.	3d Series.	Mean.
Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
50.00	.4850	.4860	.4855	.4855
100.00	.9850	.9870	.9830	.9850
200.00	1.9850	1.9860	1.9840	1.9850
300.00	2.9890	2.9875	2.9870	2.9878
400.00	3.9830	3.9800	3.9890	3.9840
500.00	4.9850	4.9850	4.9900	4.9867

Multiplying the mean of these readings by 100 and subtracting the result from the corresponding distance, we obtain the following table:

Distances.	Mean of Stadia Readings times 100.	Differences.	Variations from mean.
Feet.	*Feet.*	*Feet.*	*Feet.*
50.00	48.55	1.45	+.02
100.00	98.50	1.50	+.07
200.00	198.50	1.50	+.07
300.00	298.78	1.22	—.21
400.00	398.40	1.60	+.17
500.00	498.67	1.33	—.10

Sum of differences = 8.60;
Mean of difference = 1.43.

The variations between the numbers of the column of differences are slight, the maximum from a mean value of 1.43 feet being only .21 feet. A study of the tables will show that these variations have no apparent relation to the length of the sight, and as, in the maximum case, the variation corresponds to a reading on the rod of only .0021 feet, (an amount much within the limits of accuracy of any ordinary sight,) we are perfectly justified in concluding that these variations are accidental, and that the "difference" is, for all practical purposes, a *constant* value.*

*Mr. Benjamin Smith Lyman has kindly furnished me with the following deductions from the above tables, as an indication of the exactness of stadia measurements:

We thus see that with a telescope having a compound, plano-convex objective, whatever the formula may be, expressing the relation between d, f, x, etc., the horizontal distance is equal to a *constant* times the reading on the rod plus a *constant*, and may, as in the other cases, be expressed by the equation,

$$d = ak + c^{*}$$

The following tables, for the reduction of stadia field observations, have been computed from formulæ (5) and (6) respectively (page 331).

Distances.	*Variations from mean.*			*Error (or variation from mean) in parts of the distance measured.*			*Mean magnitude.*
50 ft.	+.07	—.03	+.02	+.00133	—.00066	+.00033	.000777
100 "	+.07	—.13	+.27	+.00066	—.00133	+.00266	.001555
200 "	+.07	—.03	+.17	+.00033	—.00016	+.00083	.000444
300 "	—.33	—.18	—.13	—.00111	—.00061	—.00044	.000722
400 "	+.27	+.57	—.33	+.00066	+.00142	—.00083	.000972
500 "	+.07	+.07	—.43	+.00013	+.00013	—.00086	.000377
							6).004841
							.000808

"We see then that the mean of the errors is .000808, (or $\frac{1}{1237}$,) which, so far as the insufficient number of eighteen sights can show, would be the mean of the errors of an infinite number of trials, and would correspond to a probable error of .000683, or $\frac{1}{1464}$ for any one of the number of trials (that is, in general, for any trial,) of the same kind. This is nearly two thirds the exactness I claimed as possible for the stadia, with a telescope magnifying ten times linear, in my paper published in the Franklin Institute Journal, (May and June, 1868.) The difference may be due, perhaps to some cause which I did not consider, such as a slight leaning of the rod forward or backward, inexactness in placing the face of the rod precisely at the station, imperfect graduation of the rod, imperfect cleanliness or transparency of the glasses or of the air, imperfection in the shape of the lenses or in their adjustments to one another, inferior lighting of the magnified image as compared with the unmagnified one, waviness from the varying refraction of the air, with the warm air rising from the sun-heated ground, inaccurate focusing, inexact placing of the center hair upon the center of the target, or graduation. This last difficulty might be avoided by taking one edge of the upper or lower cross hairs, and by special painting of the target for the center hair. * * * But at any rate the superior exactness of stadia measurement over chaining is shown, so far as eighteen trials could do it."

*This may seem a statement of what was already a well known fact. But, heretofore, it has been assumed to be a direct deduction from optical principles, and as, according to the preceding article, this is not so clearly evident, it seemed necessary to redetermine the point.

The vertical columns, in the tables, consist of two series of numbers for each degree, which series represent respectively the different values of $a\,k\,\cos^2 n$ and $ak\,\frac{\sin 2n}{2}$ for every two minutes, when $a\,k=100$. To obtain the horizontal distance (D) or the difference of level (Q), in any case, the corresponding value of $c\cos n$ or $c\sin n$ must further be added, and the mean of each of these expressions for every degree is given under each column for three of the most common values of c.

Example.

Let it be required to find the horizontal distance and the difference of level when;

$$n=+6°\ 18',$$
$$a\,k=570,\text{ and}$$
$$c=.75.$$

In the column headed 6°, opposite 18′, in the series for "Hor. Dist.," we find 98.80 as the expression for $a\,k\cos^2 n$, when $a\,k=100$; therefore, when $a\,k=570$;

$$a\,k\cos^2 n=98.80\times5.70=563.16.$$

To this must be added $c\cos n$ which, in this case, is found in the subjoined column to be .75.

Therefore the required horizontal distance is

$$563.16+.75=563.91.$$

In a similar manner, the required difference of level is

$$+10.91\times5.70+.08=+62.27.$$

One multiplication and one addition must be made in each case.

It is to be noticed, that, with the smaller angles, cos n in the expression $c\cos n$, and $c\sin n$ may be entirely neglected without appreciable error.

For values of c which differ from those given, an approximate correction, proportional to the amount of difference may very easily be made in these two expressions.

M.	0° Hor. Dist.	0° Diff. Elev.	1° Hor. Dist.	1° Diff. Elev.	2° Hor. Dist.	2° Diff. Elev.	3° Hor. Dist.	3° Diff. Elev.	4° Hor. Dist.	4° Diff. Elev.	5° Hor. Dist.	5° Diff. Elev.	6° Hor. Dist.	6° Diff. Elev.	7° Hor. Dist.	7° Diff. Elev.	8° Hor. Dist.	8° Diff. Elev.	9° Hor. Dist.	9° Diff. Elev.	10° Hor. Dist.	10° Diff. Elev.	M.
0′, . .	100.00	.00	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78	97.55	15.45	96.98	17.10	. . 0′
2, . .	“	.06	“	1.80	99.87	3.55	99.72	5.28	“	7.02	99.23	8.74	98.90	10.45	98.50	12.15	98.05	13.84	97.53	15.51	96.96	17.16	. . 2
4, . . .	“	.12	“	1.86	“	3.60	99.71	5.34	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21	98.03	13.89	97.52	15.56	96.94	17.21	. . 4
6, . .	“	.17	99.96	1.92	“	3.66	“	5.40	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26	98.01	13.95	97.50	15.62	96.92	17.26	. . 6
8, . . .	“	.23	“	1.98	99.86	3.72	99.70	5.46	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32	98.00	14.01	97.48	15.67	96.90	17.32	. . 8
10, . .	“	.29	“	2.04	“	3.78	99.69	5.52	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38	97.98	14.06	97.46	15.73	96.88	17.37	. . 10
12, . . .	“	.35	“	2.09	99.85	3.84	“	5.57	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43	97.97	14.12	97.44	15.78	96.86	17.43	. . 12
14. . . .	“	.41	99.95	2.15	“	3.90	99.68	5.63	“	7.36	99.17	9.08	98.82	10.79	98.41	12.49	97.95	14.17	97.43	15.84	96.84	17.48	. . 14
16, . . .	“	.47	“	2.21	99.84	3.95	“	5.69	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55	97.93	14.23	97.41	15.89	96.82	17.54	16
18, . . .	“	.52	“	2.27	“	4.01	99.67	5.75	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60	97.92	14.28	97.39	15.95	96.80	17.59	. . 18
20, . . .	“	.58	“	2.33	99.83	4.07	99.66	5.80	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66	97.90	14.34	97.37	16.00	96.78	17.65	. . 20
22, . . .	“	.64	99.94	2.38	“	4.13	“	5.86	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72	97.88	14.40	97.35	16.06	96.76	17.70	22
24. . . .	“	.70	“	2.44	99.82	4.18	99.65	5.92	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77	97.87	14.45	97.33	16.11	96.74	17.76	. . 24
26, . . .	99.99	.76	“	2.50	“	4.24	99.64	5.98	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83	97.85	14.51	97.31	16.17	96.72	17.81	. . 26
28, . . .	“	.81	99.93	2.56	99.81	4.30	99.63	6.04	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88	97.83	14.56	97.29	16.22	96.70	17.86	28
30, . . .	“	.87	“	2.62	“	4.36	“	6.09	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94	97.82	14.62	97.28	16.28	96.68	17.92	. 30
32, . . .	“	.93	“	2.67	99.80	4.42	99.62	6.15	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00	97.80	14.67	97.26	16.33	96.66	17.97	. . 32
34, . . .	“	.99	“	2.73	“	4.48	“	6.21	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05	97.78	14.73	97.24	16.39	96.64	18.03	. . 34
36, . . .	“	1.05	99.92	2.79	99.79	4.53	99.61	6.27	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11	97.76	14.79	97.22	16.44	96.62	18.08	36
38, . . .	“	1.11	“	2.85	“	4.59	99.60	6.33	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17	97.75	14.84	97.20	16.50	96.60	18.14	. . 38
40, . . .	“	1.16	“	2.91	99.78	4.65	99.59	6.38	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22	97.73	14.90	97.18	16.55	96.57	18.19	. 40
42, . . .	“	1.22	99.91	2.97	“	4.71	“	6.44	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28	97.71	14.95	97.16	16.61	96.55	18.24	. 42
44, . . .	99.98	1.28	“	3.02	99.77	4.76	99.58	6.50	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33	97.69	15.01	97.14	16.66	96.53	18.30	44
46, . . .	“	1.34	99.90	3.08	“	4.82	99.57	6.56	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39	97.68	15.06	97.12	16.72	96.51	18.35	46
48, . . .	“	1.40	“	3.14	99.76	4.88	99.56	6.61	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45	97.66	15.12	97.10	16.77	96.49	18.41	48
50, . .	“	1.45	“	3.20	“	4.94	“	6.67	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50	97.64	15.17	97.08	16.83	96.47	18.46	50
52, .	“	1.51	99.89	3.26	99.75	4.99	99.55	6.73	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56	97.62	15.23	97.06	16.88	96.45	18.51	52
54, . . .	“	1.57	“	3.31	99.74	5.05	99.54	6.78	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61	97.61	15.28	97.04	16.94	96.42	18.57	. 54
56, .	99.97	1.63	“	3.37	“	5.11	99.53	6.84	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67	97.59	15.34	97.02	16.99	96.40	18.62	. 56
58, . .	“	1.69	99.88	3.43	99.73	5.17	99.52	6.90	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73	97.57	15.40	97.00	17.05	96.33	18.68	. . 58
60, . .	“	1.74	“	3.49	“	5.23	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73	. . 60
c= .75,	.75	.01	.75	.02	.75	.03	.75	.05	.75	.06	.75	.07	.75	.08	.74	.10	.74	.11	.74	.12	.74	.14	c= .75
c=1.00,	1.00	.01	1.00	.03	1.00	.04	1.00	.06	1.00	.08	.99	.09	.99	.11	.99	.13	.99	.15	.99	.16	.98	.18	c=1.00
c=1.25,	1.25	.02	1.25	.03	1.25	.05	1.25	.08	1.25	.10	1.24	.11	1.24	.14	1.24	.16	1.23	.18	1.23	.21	1.23	.23	c=1.25

M.	11° Hor. Dist.	11° Diff. Elev.	12° Hor. Dist.	12° Diff. Elev.	13° Hor. Dist.	13° Diff. Elev.	14° Hor. Dist.	14° Diff. Elev.	15° Hor. Dist.	15° Diff. Elev.	16° Hor. Dist.	16° Diff. Elev.	17° Hor. Dist.	17° Diff. Elev.	18° Hor. Dist.	18° Diff. Elev.	19° Hor. Dist.	19° Diff. Elev.	20° Hor. Dist.	20° Diff. Elev.	M.
0′	96.36	18.73	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14	0′
2	96.34	18.78	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83	88.26	32.18	2
4	96.32	18.84	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87	88.23	32.23	4
6	96.29	18.89	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92	88.19	32.27	6
8	96.27	18.95	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97	88.15	32.32	8
10	96.25	19.00	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01	88.11	32.36	10
12	96.23	19.05	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06	88.08	32.41	12
14	96.21	19.11	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10	88.04	32.45	14
16	96.18	19.16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15	88.00	32.49	16
18	96.16	19.21	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19	87.96	32.54	18
20	96.14	19.27	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24	87.93	32.58	20
22	96.12	19.32	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28	87.89	32.63	22
24	96.09	19.38	95.39	20.97	91.63	22.54	93.81	24.09	92.95	25.60	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33	87.85	32.67	24
26	96.07	19.43	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38	87.81	32.72	26
28	95.05	19.48	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42	87.77	32.76	28
30	96.03	19.54	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47	87.74	32.80	30
32	96.00	19.59	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51	87.70	32.85	32
34	95.98	19.64	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56	87.66	32.89	34
36	95.96	19.70	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60	87.62	32.93	36
38	95.93	19.75	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65	87.58	32.98	38
40	95.91	19.80	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69	87.54	33.02	40
42	95.89	19.86	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74	87.51	33.07	42
44	95.86	19.91	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78	87.47	33.11	44
46	95.84	19.96	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83	87.43	33.15	46
48	95.82	20.02	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87	87.39	33.20	48
50	95.79	20.07	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92	87.35	32.24	50
52	95.77	20.12	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96	87.31	33.28	52
54	95.75	20.18	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01	87.27	33.33	54
56	95.72	20.23	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05	87.24	33.37	56
58	95.70	20.28	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45	91.43	27.91	90.48	29.34	89.44	30.74	88.34	32.09	87.20	33.41	58
60	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14	87.16	33.46	60
c = .75	.73	.15	.73	.16	.73	.17	.73	.19	.72	.20	.72	.21	.72	.23	.71	.24	.71	.25	.70	.26	c = .75
c = 1.00	.98	.20	.98	.22	.97	.23	.97	.25	.96	.27	.86	.28	.95	.30	.95	.32	.94	.33	.94	.35	c = 1.00
c = 1.25	1.22	.25	1.22	.27	1.21	.29	1.21	.31	1.20	.34	1.20	.35	1.19	.38	1.19	.40	1.18	.42	1.17	.44	c = 1.25

M.	21° Hor. Dist.	21° Diff. Elev.	22° Hor. Dist.	22° Diff. Elev.	23° Hor. Dist.	23° Diff. Elev.	24° Hor. Dist.	24° Diff. Elev.	25° Hor. Dist.	25° Diff. Elev.	26° Hor. Dist.	26° Diff. Elev.	27° Hor. Dist.	27° Diff. Elev.	28° Hor. Dist.	28° Diff. Elev.	29° Hor. Dist.	29° Diff. Elev.	30° Hor. Dist.	30° Diff. Elev.	M.
0′, . . .	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45	76.50	42.40	75.00	43.30	. . . 0′
2, ...	87.12	33.50	85.93	34.77	84.69	36.01	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49	77.91	41.48	76.45	42.43	74.95	43.33	. . . 2
4, ...	87.08	33.54	85.89	34.82	84.65	36.05	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52	77.86	41.52	76.40	42.46	74.90	43.36	. . . 4
6, ...	87.04	33.59	85.85	34.86	84.61	36.09	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55	77.81	41.55	76.35	42.49	74.85	43.39	. . 6
8, ...	87.00	33.63	85.80	34.90	84.57	36.13	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59	77.77	41.58	76.30	42.53	74.80	43.42	. . 8
10, ...	86.96	33.67	85.76	34.94	84.52	36.17	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62	77.72	41.61	76.25	42.56	74.75	43.45	. . . 10
12, ...	86.92	33.72	85.72	34.98	84.48	36.21	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66	77.67	41.65	76.20	42.59	74.70	43.47	. . . 12
14, ...	86.88	33.76	85.68	35.02	84.44	36.25	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69	77.62	41.68	76.15	42.62	74.65	43.50	. . . 14
16, ...	86.84	33.80	85.64	35.07	84.40	36.29	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72	77.57	41.71	76.10	42.65	74.60	43.53	. . . 16
18, ...	86.80	33.84	85.60	35.11	84.35	36.33	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76	77.52	41.74	76.05	42.68	74.55	43.56	. . 18
20, ...	86.77	33.89	85.56	35.15	84.31	36.37	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79	77.48	41.77	76.00	42.71	74.49	43.59	. . 20
22, ...	86.73	33.93	85.52	35.19	84.27	36.41	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82	77.42	41.81	75.95	42.74	74.44	43.62	. . 22
24, ...	86.69	33.97	85.48	35.23	84.23	36.45	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86	77.38	41.84	75.90	42.77	74.39	43.65	. . 24
26, ...	86.65	34.01	85.44	35.27	84.18	36.49	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89	77.33	41.87	75.85	42.80	74.34	43.67	. . 26
28, ...	86.61	34.06	85.40	35.31	84.14	36.53	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92	77.28	41.90	75.80	42.83	74.29	43.70	. . 28
30, ...	86.57	34.10	85.36	35.36	84.10	36.57	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96	77.23	41.93	75.75	42.86	74.24	43.73	. . 30
32, ...	86.53	34.14	85.31	35.40	84.06	36.61	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99	77.18	41.97	75.70	42.89	74.19	43.76	. . 32
34, ...	86.49	34.18	85.27	35.44	84.01	36.65	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02	77.13	42.00	75.65	42.92	74.14	43.79	. . . 34
36, ...	86.45	34.23	85.23	35.48	83.97	36.69	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06	77.09	42.03	75.60	42.95	74.09	43.82	. . 36
38, ...	86.41	34.27	85.19	35.52	83.93	36.73	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09	77.04	42.06	75.55	42.98	74.04	43.84	. . . 38
40, ...	86.37	34.31	85.15	35.56	83.89	36.77	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12	76.99	42.09	75.50	43.01	73.99	43.87	. . 40
42, ...	86.33	34.35	85.11	35.60	83.84	36.80	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16	76.94	42.12	75.45	43.04	73.93	43.90	. . . 42
44, ...	86.29	34.40	85.07	35.64	83.80	36.84	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19	76.89	42.15	75.40	43.07	73.88	43.93	. . 44
46, ...	86.25	34.44	85.02	35.68	83.76	36.88	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22	76.84	42.19	75.35	43.10	73.83	43.95	. . . 46
48, . . .	86.21	34.48	84.98	35.72	83.72	36.92	82.41	38.08	81.06	39.13	79.67	40.24	78.25	41.26	76.79	42.22	75.30	43.13	73.78	43.98	. . 48
50, ...	86.17	34.52	84.94	35.76	83.67	36.96	82.33	38.11	81.01	39.22	79.62	40.28	78.20	41.29	76.74	42.25	75.25	43.16	73.73	44.01	. . 50
52, . . .	86.13	34.57	84.90	35.80	83.63	37.00	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32	76.69	42.28	75.20	43.18	73.68	44.04	. . 52
54, ...	86.09	34.61	84.86	35.85	83.59	37.04	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35	76.64	42.31	75.15	43.21	73.63	44.07	. . . 54
56, ...	86.05	34.65	84.82	35.89	83.54	37.08	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39	76.59	42.34	75.10	43.24	73.58	44.09	. . 56
58, ...	86.01	34.69	84.77	35.93	83.50	37.12	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42	76.55	42.37	75.05	43.27	73.52	44.12	. . 58
60, ...	85.97	34.73	84.73	35.97	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45	76.50	42.40	75.00	43.30	73.47	44.15	. . 60
c= .75, .	.70	.27	.69	.29	.69	.30	.68	.31	.68	.32	.67	.33	.66	.35	.66	.36	.65	.37	.65	.38	c= .75
c=1.00, .	.93	.37	.92	.38	.92	.40	.91	.41	.90	.43	.89	.45	.89	.46	.88	.48	.87	.49	.86	.51	c=1.00
c=1.25, .	1.16	.46	1.15	.48	1.15	.50	1.14	.52	1.13	.54	1.12	.56	1.11	.58	1.10	.60	1.09	.62	1.08	.64	c=1.25

GENERAL INDEX

TO THE

FIRST REPORT OF PROGRESS

IN THE

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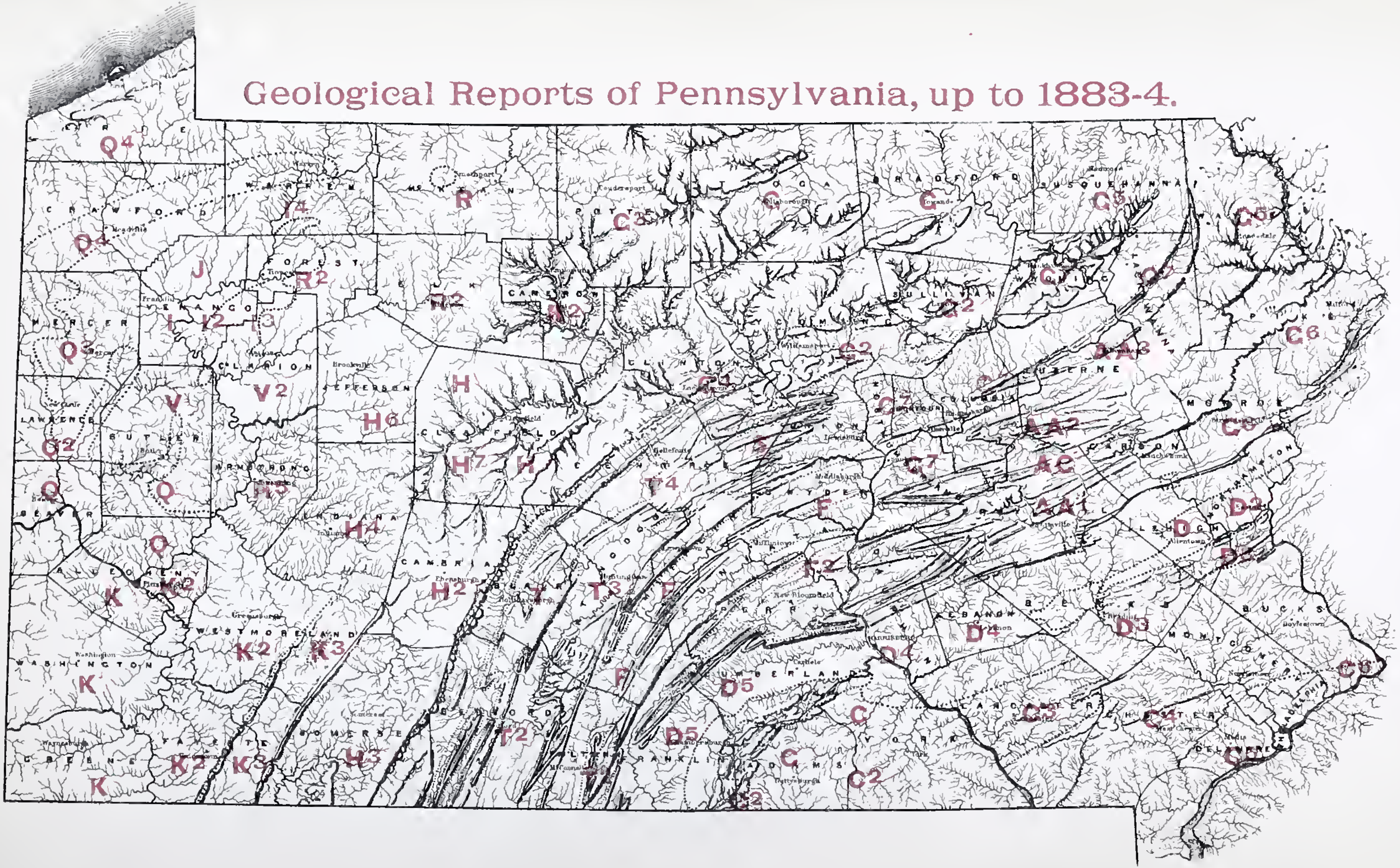
Geological Reports of Pennsylvania, up to 1883-4.



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Communications relating to the work of the survey should be addressed to J. Peter Lesley, State Geologist, No. 1008 Clinton street, Philadelphia, and those intended for the Board of Commissioners, to William A. Ingham, Secretary, No. 320 Walnut street, Philadelphia.

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J. SIMPSON AFRICA,
Secretary of Internal Affairs,
Harrisburg, Pa.

October 4, 1883.